The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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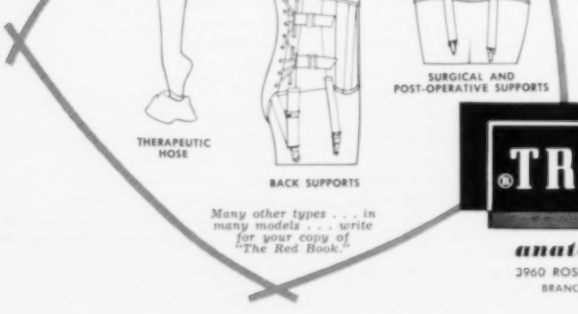

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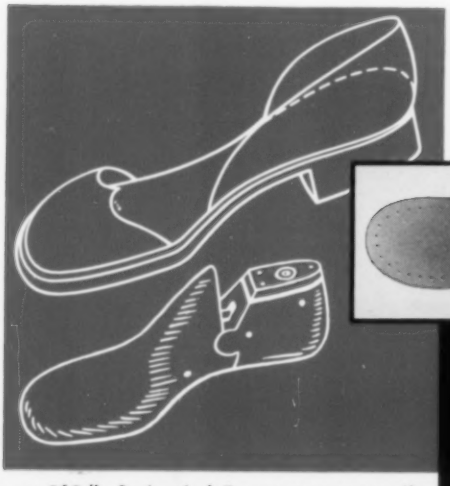

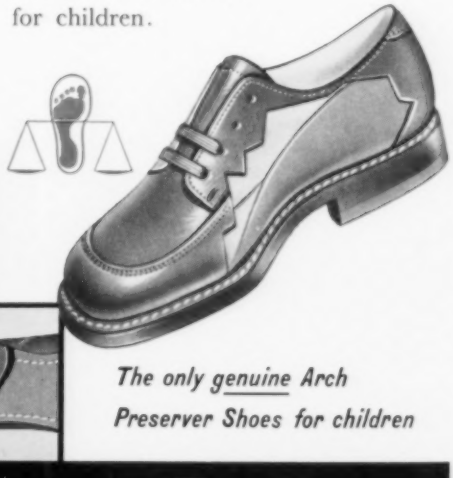

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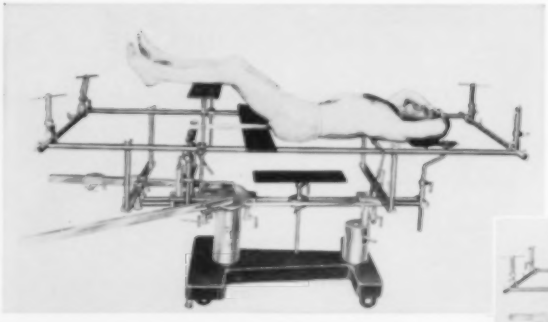

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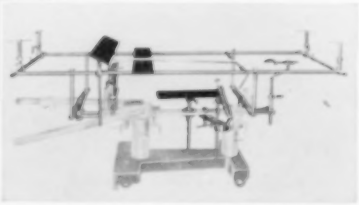

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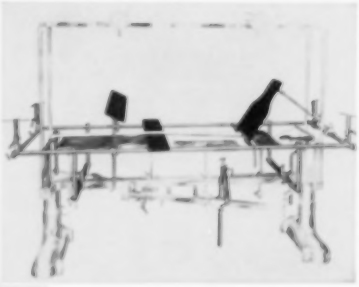

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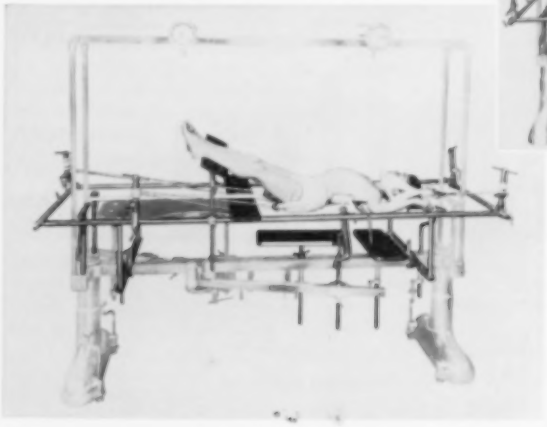

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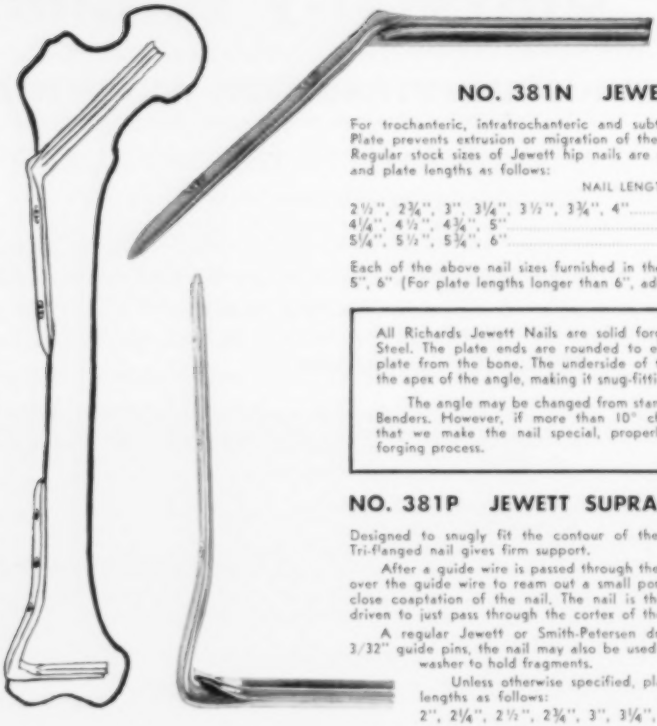

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Each of the above nail sizes furnished in the following plate lengths: 2", 3", 4", 5", 6" (For plate lengths longer than 6", add $1.25 per inch).

All Richards Jewett Nails are solid forged of one piece SMO Stainless Steel. The plate ends are rounded to eliminate abrupt protrusion of the plate from the bone. The underside of the plate is curved completely to the apex of the angle, making it snug-fitting to the bone.

The angle may be changed from standard by using the No. 414 Jewett Benders. However, if more than 10° change is desired, we recommend that we make the nail special, properly forming the angle in our hot forging process.

NO. 381P JEWETT SUPRACONDYLAR NAIL

Designed to snugly fit the contour of the condyles and shaft of the femur. Tri-flanged nail gives firm support.

After a guide wire is passed through the condyles, a ½" D. reamer is placed over the guide wire to ream out a small portion of the lateral cortex to provide close coaptation of the nail. The nail is then placed over the guide wire and driven to just pass through the cortex of the medial condyle.

A regular Jewett or Smith-Petersen driver may be used. Cannulated for 3/32" guide pins, the nail may also be used in conjunction with a tibia bolt and washer to hold fragments.

Unless otherwise specified, plate length of 6" furnished, with nail lengths as follows:

2", 2¼", 2½", 2¾", 3", 3¼", 3½", 3¾", 4" **$17.50**

NO. 381S JEWETT SHOULDER NAIL

Indicated for fractures of the upper end of the humerus, mainly in the surgical neck area, or in fractures involving both the anatomical and the surgical neck in some instances.

Also adaptable for rotation osteotomies in the upper end of the femur in the young patient. The nail is not long enough to go into the epiphysis of the head of the femur yet is long enough to give stability with the use of a plaster spica. Nail is removed following complete healing of the bone.

Reduced in all dimensions from regular Jewett Nail. Non-cannulated. Plate length 2"; nail lengths as follows:

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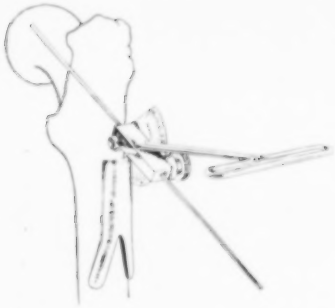

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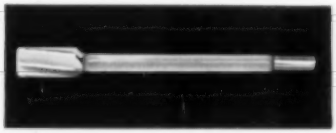

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Non-adjustable. For use as a drill jig only, giving an exact angle of 135° to the guide wire. Stainless.

NO. 381D DRIVER, stainless ..... $ 7.00
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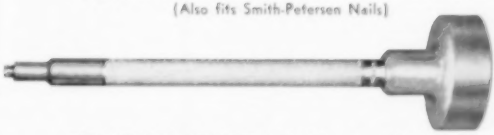

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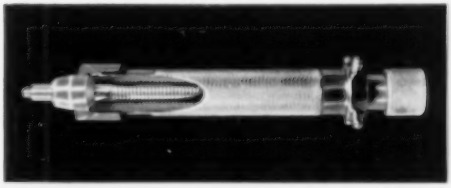
NO. 106B GUIDE PIN, Calibrated, stainless
$1.25 each ..... $14.00 doz.



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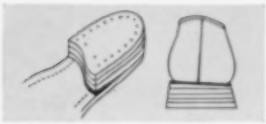

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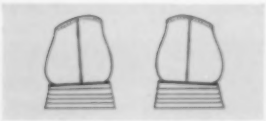

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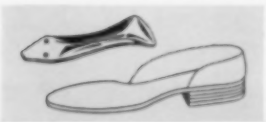

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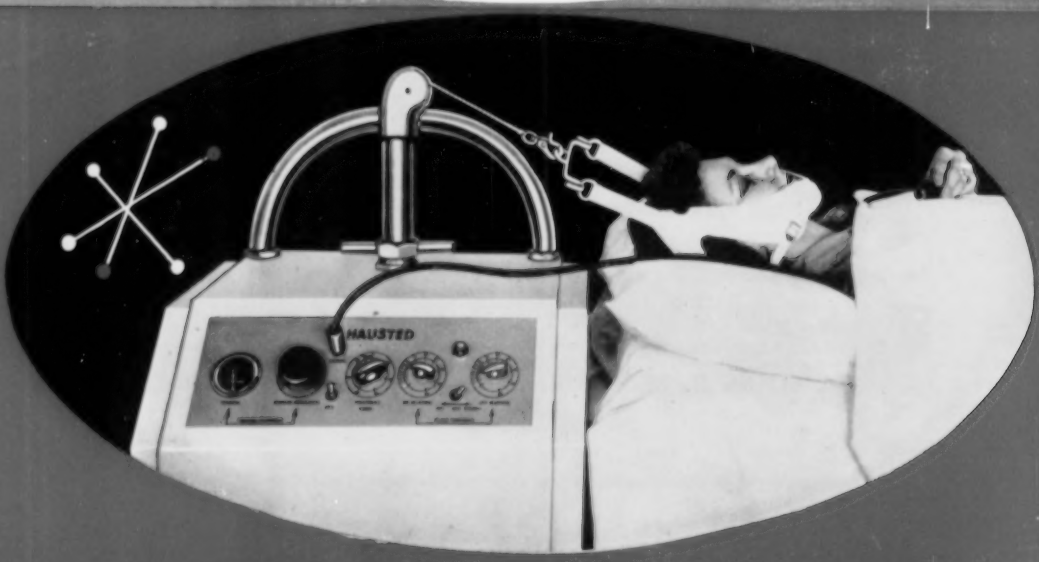

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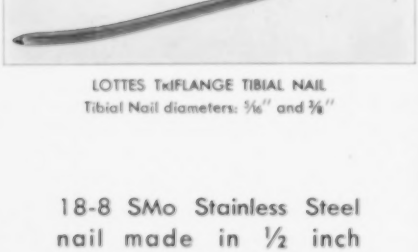

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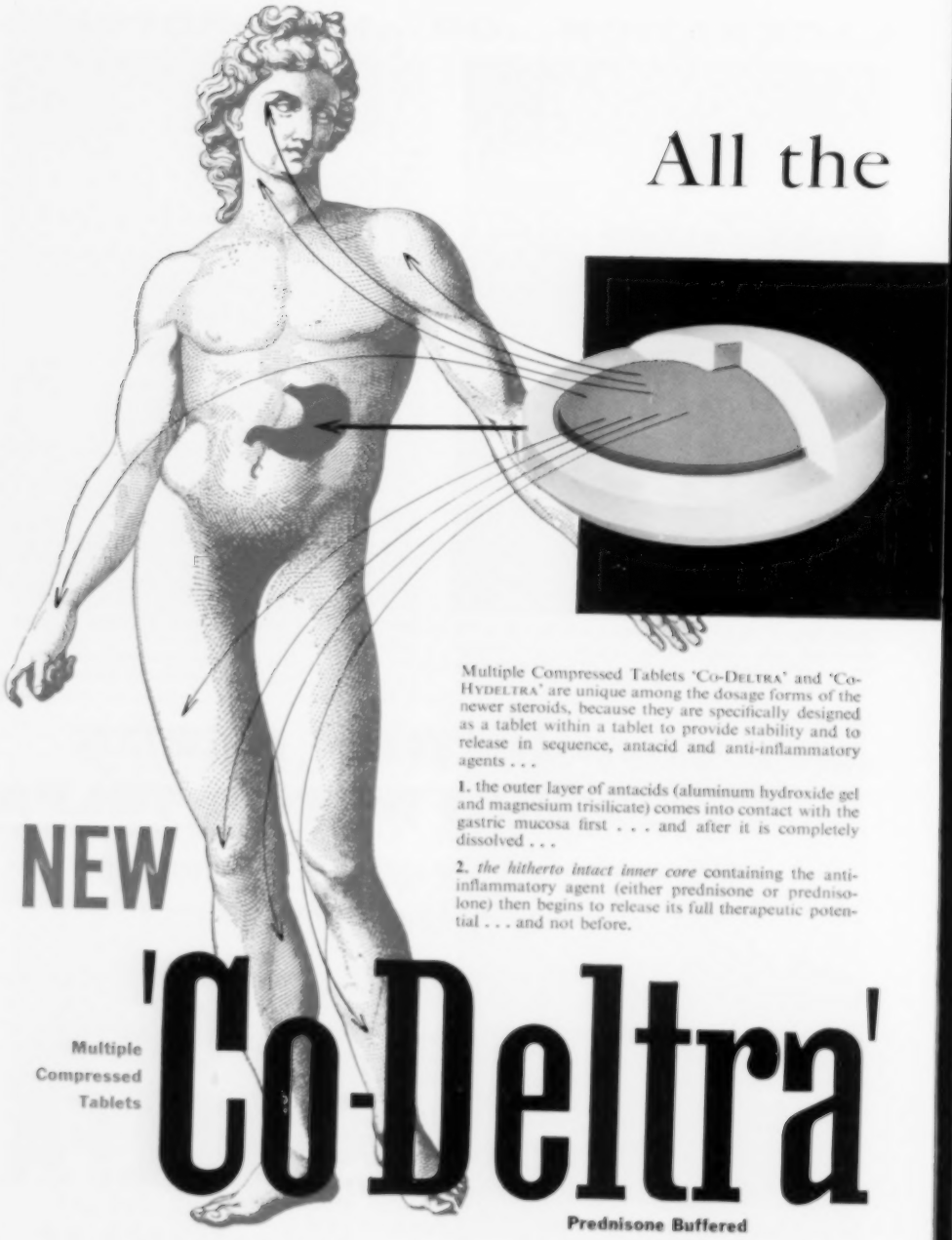

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1. Bollet, A. J., Black, R., and Bunim, J. J.: *J.A.M.A.* **158**: 459, June 11, 1955.

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A Laboratory and Clinical Report on Adrenosem® Salicylate

(BRAND OF CARBAZOCHROME SALICYLATE)

History

The first investigation of a hemostat with an action comparable to Adrenosem Salicylate was made by Derouaux and Roskam[1] in 1937. They reported that an oxidation product of adrenalin, adrenochrome (which has no sympathomimetic properties), has prompt hemostatic activity.

It was further found that various combinations of adrenochrome, notably the oxime and semicarbazone, produced stable solutions. But, these were so slightly soluble that sufficient concentration could not be obtained for practical therapeutic use. By combining these adrenochrome compounds in a sodium salicylate complex a stable, soluble form can be obtained. This complex has been given the generic name, carbazochrome salicylate, and is supplied under the trade name Adrenosem Salicylate.

Roskam, in his study entitled "The Arrest of Bleeding,"[2] enumerates "the drugs whose efficaciousness as hemostatics have been proved by accurate methods in experimental animals and in healthy men as well. . . . One is the monosemicarbazone of adrenochrome [Adrenosem Salicylate]."

Chemistry

Adrenosem Salicylate is a synthetic chemical. The full chemical name is adrenochrome monosemicarbazone sodium salicylate complex.

Pharmacology

Although it is chemically related to epinephrine, Adrenosem Salicylate has no sympathomimetic effects. It does not alter blood components, nor does it affect blood pressure or cardiac rate.[2-7]

(* U.S. Patent 2,581,850)

Sherber, in an early study,[3] concludes that Adrenosem Salicylate* "is a potent antihemorrhagic factor in those conditions in which the integrity of the smaller vessels is interrupted, and is superior to any similar material that is now available."

He continues, "From our experience it appears that adrenochromazone complex is indicated in preventing vascular accidents incident to hypertension; in maintaining small vessel integrity; in the preoperative preparation where oozing from a vascular bed is anticipated, as in tonsillectomies, adenoidectomies and prostatectomies; and as an adjunct in the treatment of bleeding from such surgical procedures."

Adrenosem Salicylate may be administered simultaneously (but separately) with any type of anesthetic, anticoagulant, or vitamin K and heparin.

A Unique Systemic Hemostat

Clinical investigators[2-7] are in agreement that Adrenosem Salicylate controls bleeding and oozing by decreasing capillary permeability and by promoting the retraction of severed capillary ends. It aids in maintaining normal capillary integrity by direct action on the intercellular "cement" in capillary walls. The interesting work of Fulton[8] confirms this. Adrenosem Salicylate, since it is not a vasoconstrictor, has no effect on large severed blood vessels and arterioles.

Adrenosem Salicylate is being used both prophylactically and therapeutically in thousands of hospitals, and in virtually every type of surgical procedure. It has also proved most useful in dental surgery.[7]

Owings reported on the use of Adrenosem Salicylate in controlling postoperative adenoid bleeding in 102 cases.[4] "We have used 2½ mg.

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(½ ampule) intramuscularly, 15 minutes before anesthesia for children and 5 mg. (1 ampule) for adults." In only one patient did bleeding occur. Three others showed red blood from the nose and mouth. These patients "were then given 5 mg. intramuscularly, with prompt and complete control. We have also noticed that bleeding stopped more promptly on the operating table."

This is a 1% incidence of postoperative bleeding using Adrenosem Salicylate preoperatively, compared to an incidence of 10% postoperative bleeding in all cases taken from previous records, without Adrenosem Salicylate medication.

Peele reports on the use of Adrenosem Salicylate in treating 178 patients with 24 different conditions.[5] The drug was first used to control postoperative hemorrhage from the adenoid region. He adds: "The results were so dramatic that since that date [1953] Adrenosem Salicylate has been used postoperatively to reduce bleeding from all otolaryngologic and bronchoesophagolic procedures, to treat postoperative hemorrhage from the tonsil and adenoid regions, and to treat selected cases of epistaxis."

The effectiveness of Adrenosem Salicylate in controlling bleeding and oozing in 330 patients is reviewed by Bacala.[6] "Our experience of the effect of carbazochrome salicylate on 317 surgical indications and 13 obstetricogynecological conditions, has been therapeutically encouraging and successful for the control of capillary bleeding. Foremost among the cases studied were 223 tonsillectomies definitely benefited by this metabolic hemostat, making a diminution of the control incidence of posttonsillectomy bleeding of 19.8% down to 7%. It has also been found useful in gastro-intestinal bleeding, cataract extraction, epistaxis, incisional seepage, trans-urethral prostatectomy, menometrorrhagias, cervical ooze, antepartum and postpartum bleeding, threatened abortion, and prevention of capillary hemorrhages during hedulin or dicumerol therapy."

Side Effects

All investigators concur that, at recommended dosage levels, Adrenosem Salicylate is free from toxic effects. No cumulative effects attributable to the drug have been reported.

The only side reaction noted has been a transient stinging sensation in the area of injection when Adrenosem Salicylate is used intramuscularly. As one investigator comments: "The brief discomfort which attends the injection of Adrenosem into the gluteal region has not been a significant problem in children or adults as originally anticipated."[5]

Indications

Idiopathic purpura, retinal hemorrhage, familial telangiectasia, epistaxis, hemoptysis, hematuria.

Postoperative bleeding associated with:
tonsillectomy, adenoidectomy and
nasopharynx surgery;
prostatic and bladder surgery;
uterine bleeding;
postpartum hemorrhage;
dental surgery;
chest surgery and chronic pulmonary bleeding.

Dosage

For recommended dosage schedules, please send for detailed literature.

Supplied

Ampuls: 5 mg., 1 cc. (package of 5).
Tablets: 1 mg. S.C. Orange, bottles of 50.
Tablets: 2.5 mg. S.C. Yellow, bottles of 50.
Syrup: 2.5 mg. per 5 cc. (1 tsp.), 4 ounce bottles.

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8. Fulton, M.D., Dept. of Biology, Boston University: Personal Communication.

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- **controls emergence excitement**

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'Thorazine' should be administered discriminately; and, before prescribing, the physician should be fully conversant with the available literature.

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Unit Complete except for Rhinoplastic Saw and Standard and Mayo Table **695.00**

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VOLUME I

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fastest acting local anesthetic—as safe as it is effective

How safe is Xylocaine? In five years, over 500,000,000 injections of Xylocaine HCl Solution have been given. "The apparent clinical safety of Xylocaine is gratifying, for without this quality, its additional properties would not warrant an enthusiastic report. Nor would safety alone call for a high recommendation unless additional desirable properties were to be found. The truth of the matter is, however, that Xylocaine approaches the ideal drug more closely than any other local anesthetic agent we have today."*

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It has also become the choice of many physicians for *therapeutic interruption of nerve function by temporary nerve blocks* in herpes zoster, subdeltoid bursitis, fibrositis, myalgia of shoulder muscles, periarthritis due to trauma, and painful postoperative scars. The relief of pain in these conditions at times appears to be the most important part of treatment.

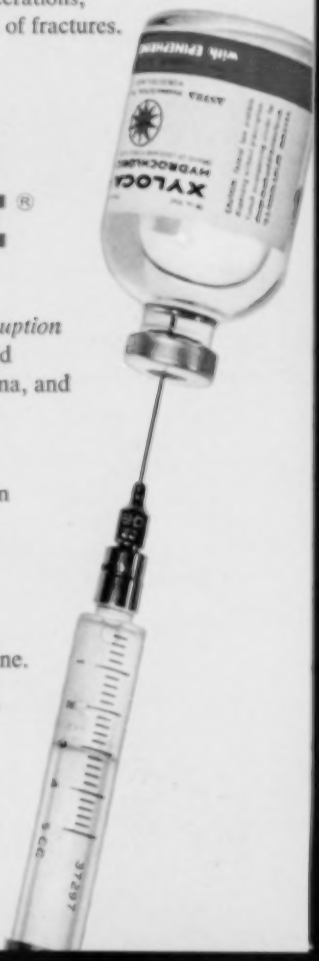
The remarkable *topical anesthetic* properties of Xylocaine HCl Solution further enhance its usefulness for minor operations. Topical anesthesia can be obtained by spraying, by applying packs, by swabbing, or by instilling the solution into a cavity or on a surface.

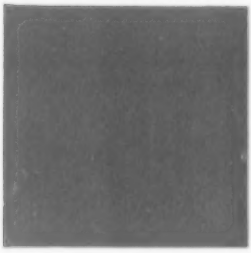
Xylocaine HCl Solutions are available in 2 cc. ampuls, 20 cc. and 50 cc. vials in strengths of 0.5%, 1% and 2%, with or without epinephrine.

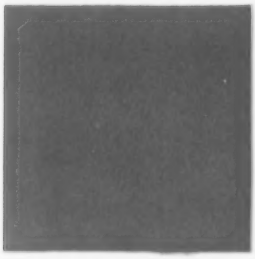
Bibliography of approximately 300 Xylocaine references upon request.

*Southworth, J. L., and Dabbs, C. H.: Xylocaine: a superior agent for conduction anesthesia, Anesth. & Analg. *32*:159 (May-June) 1953.

Astra Pharmaceutical Products, Inc., Worcester 6, Mass.







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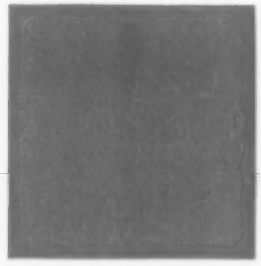

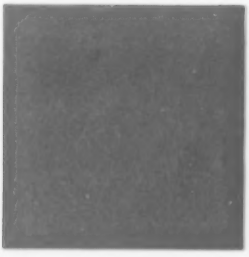

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*Reg. Trade Mark of T. J. Smith & Nephew, Ltd., England

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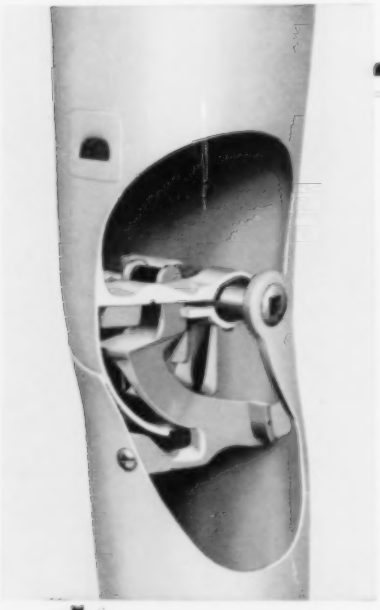

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ADJUSTS ITSELF TO THE SWELLING

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You, doctor, set the pressure, and TENSOR maintains it exactly. That's because TENSOR is made with *heat-resistant* live rubber threads—keeps its positive stretch and snap-back long after elastic bandages made with ordinary rubber are limp and lifeless. Therefore TENSOR gives with the swelling—maintains proper support *without constriction*. Give your patients the advantages of TENSOR!

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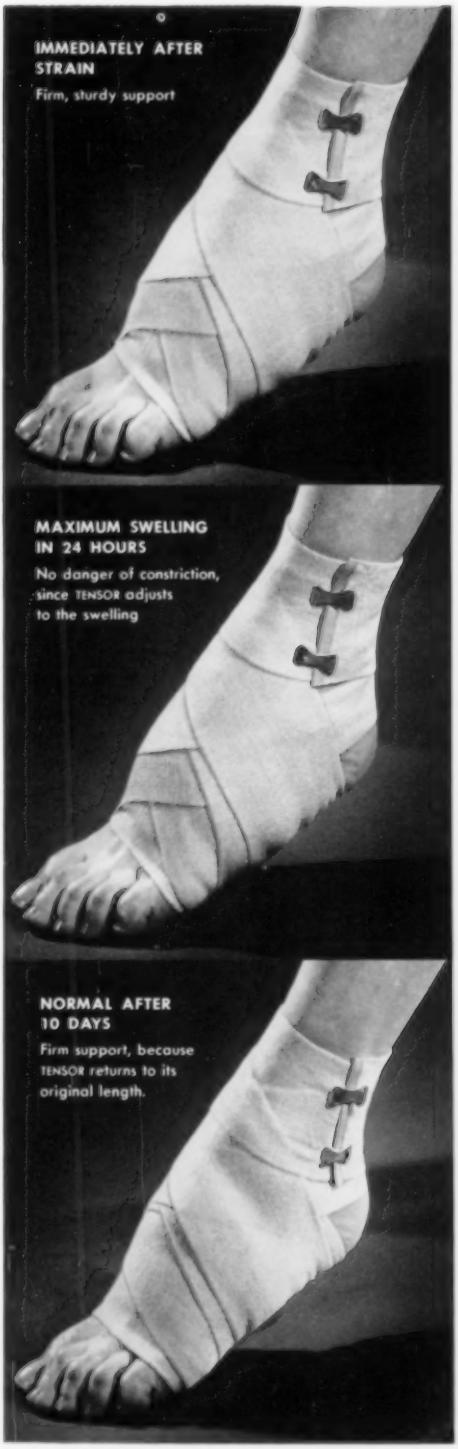
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Firm, sturdy support
MAXIMUM SWELLING IN 24 HOURS
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All the benefits of prednisone and prednisolone plus positive antacid action to minimize gastric distress

Multiple Compressed Tablets of 'Co-Deltra' and 'Co-Hydeltra' are designed to help the physician cope with the problem of gastric distress which might otherwise become an obstacle to therapy with the newer steroids prednisone and prednisolone. Each Multiple Compressed Tablet is specifically formulated as a "tablet within a tablet" to provide stability and to release in sequence antacid and anti-inflammatory components.

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MULTIPLE COMPRESSED TABLETS

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Supplied: Multiple Compressed Tablets of 'Co-Deltra' and 'Co-Hydeltra', each containing 5 mg. prednisone or prednisolone, 300 mg. of dried aluminum hydroxide gel, U.S.P., and 50 mg. of magnesium trisilicate, U.S.P., bottles of 30 tablets.

'Co-Deltra' and 'Co-Hydeltra' are the trademarks of Merck & Co., Inc.

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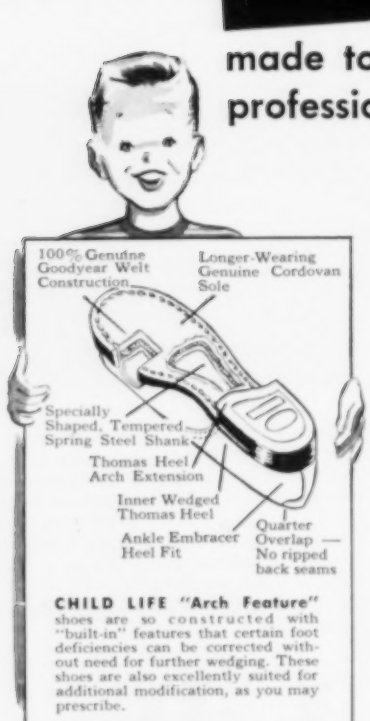
Child Life SHOES

made to merit your professional recommendation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Thomas Heel Arch Extension
Inner Wedged Thomas Heel
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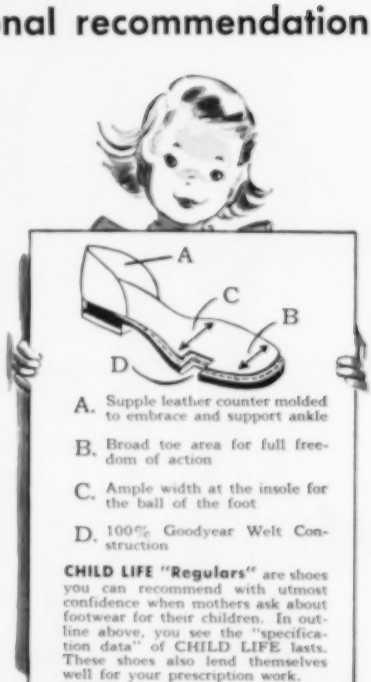
Quarter Overlap — No ripped back seams

CHILD LIFE "Arch Feature" shoes are so constructed with "built-in" features that certain foot deficiencies can be corrected without need for further wedging. These shoes are also excellently suited for additional modification, as you may prescribe.



A. Supple leather counter molded to embrace and support ankle

B. Broad toe area for full freedom of action

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CHILD LIFE "Regulars" are shoes you can recommend with utmost confidence when mothers ask about footwear for their children. In outline above, you see the "specification data" of CHILD LIFE lasts. These shoes also lend themselves well for your prescription work.

In almost every community from coast-to-coast, you'll find a qualified and franchised CHILD LIFE shoe dealer. These men and women have been selected for their knowledge of good fitting practices, and for their specific interest in children's footwear. You'll find them most co-operative and attentive to your prescription work. Please write for full information on CHILD LIFE shoes — on the market since 1924 — and the names of the CHILD LIFE dealers nearest you.

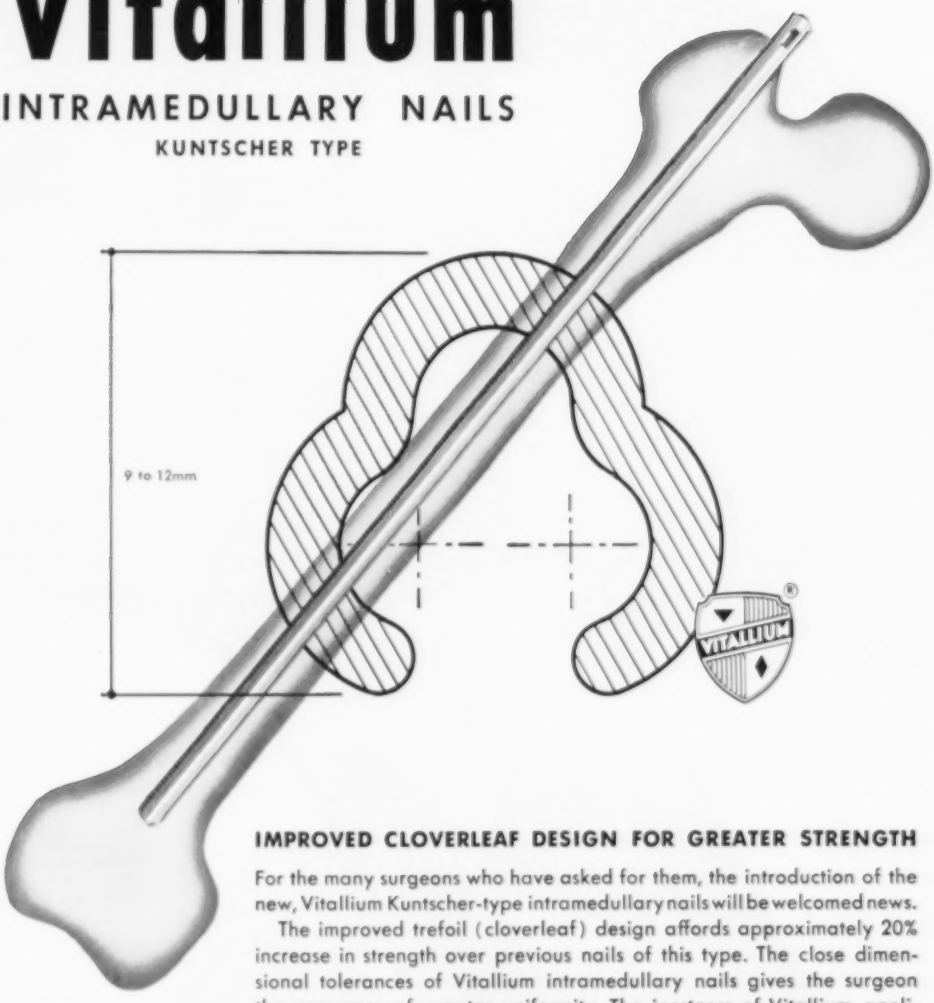
HERBST Shoe Manufacturing Company

Milwaukee 45, Wis.

Vitallium®

INTRAMEDULLARY NAILS

KUNTSCHER TYPE



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For the many surgeons who have asked for them, the introduction of the new, Vitallium Kuntscher-type intramedullary nails will be welcomed news.

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The addition of these nails to ever increasing line of Vitallium Surgical Appliances now provides the surgeon with the widest selection of appliances of one alloy for a greater number of uses in internal fixation.

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For clubfoot, fore-arm and other casts where an extremely fast-setting bandage is desired.

2" x 3 yd. 4" x 5 yd.
3" x 3 yd. 5" x 5 yd.
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For walking-boots, long-term casts—and wherever maximal strength, minimal weight and effective moisture-resistance are essential.

3" x 3 yd.
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"Specialist"®

FAST-SETTING

The bandage of choice for all general cast work.

2" x 3 yd. 5" x 5 yd.
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In remedial exercise therapy

it takes **Both..**

COMPETENT PERSONNEL

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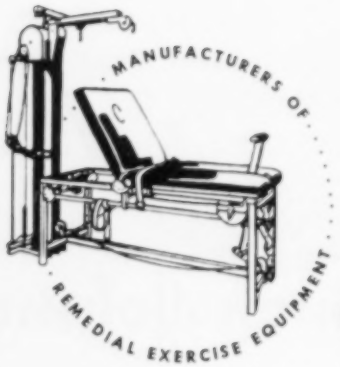
PROPER CLINICAL TOOLS

to insure the desired end results!



The Elgin Exercise Appliance Co. has specifically designed and developed, in a scientific manner, a complete line of progressive resistance exercise equipment to meet the many and varied problems of remedial exercise therapy. This equipment gives the doctor and technician the proper clinical tools with which to administer a great variety of remedial exercises for both the surgical and non-surgical patient. It also provides a wide exercise range, from simple functional exercises to the most highly definitive focal exercises.

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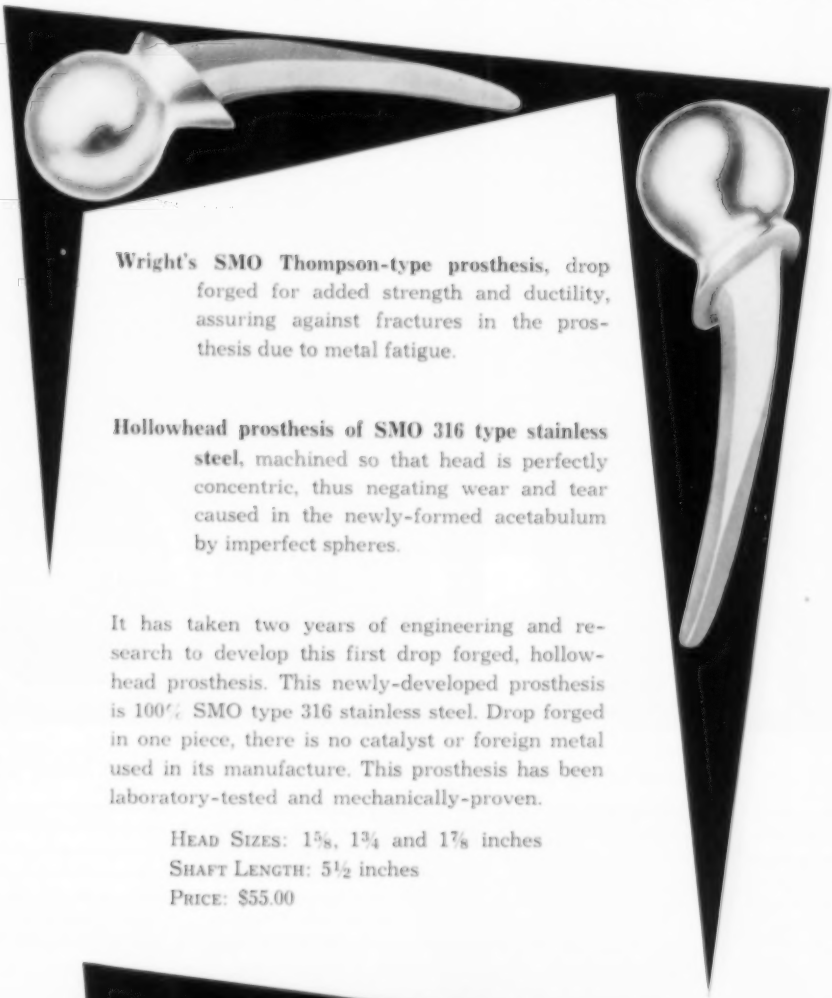
SMo Stainless Steel Drop Forged HOLLOW-HEAD HIP PROSTHESIS



Wright's SMO Thompson-type prosthesis, drop forged for added strength and ductility, assuring against fractures in the prosthesis due to metal fatigue.

Hollowhead prosthesis of SMO 316 type stainless steel, machined so that head is perfectly concentric, thus negating wear and tear caused in the newly-formed acetabulum by imperfect spheres.

It has taken two years of engineering and research to develop this first drop forged, hollow-head prosthesis. This newly-developed prosthesis is 100% SMO type 316 stainless steel. Drop forged in one piece, there is no catalyst or foreign metal used in its manufacture. This prosthesis has been laboratory-tested and mechanically-proven.

HEAD SIZES: 1⅝, 1¾ and 1⅞ inches
SHAFT LENGTH: 5½ inches
PRICE: $55.00

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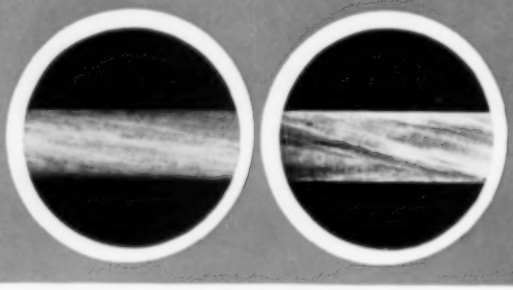
Photomicrography shows why **D & G** gut is stronger— more flexible



D & G gut

Photomicrograph* shows smooth surface of D & G SURGICAL GUT with no fraying or roughness. The soft matte finish prevents knots from slipping. No grinding to size. Full natural strength is preserved.

Another leading gut

Photomicrograph* detects surface fraying and roughness. This gut was ground to size. It appears uniform to the naked eye, but the powerful camera lens shows imperfections which may cause weakness when a knot is tied.

D & G gut

Photomicrograph** shows firm, even cohesion of plies—twisted into strands before chromicizing —for greater flexibility. Natural collagen firmly bonds the plies —holds the twist. This results in greater knot strength under stress.

Another leading gut

Photomicrograph** detects separate plies in this gut. Here each ply was chromicized before twisting into suture strand. This process limits natural bonding —lowers flexibility and tensile strength — encourages fraying.

*Medium chromic gut, 5-0; light field method; 106 x

**Medium chromic gut, 00; dark field method; 27 x

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ADVANCING WITH SURGERY

Photomicrography shows what the hand cannot feel

Photomicrographs (unretouched) by E. J. Thomas, Stamford Laboratory, Research Division of American Cyanamid Company, Stamford, Connecticut.

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CO-AXIAL SOCKET REAMERS

with the detachable shank

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Co-axial centering of shank • True symmetry • Precision cutting of cartilage, cortical and cancellous bone • Removal of cuttings • No clogging

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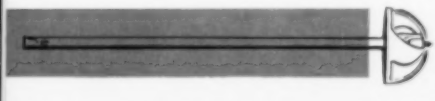

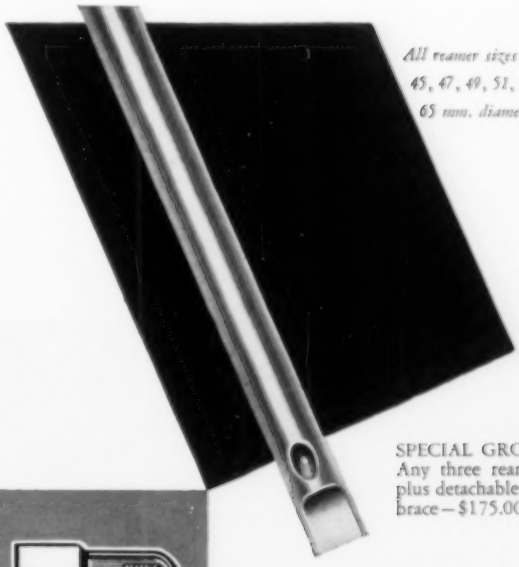

All reamer sizes—39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 61, 65 mm. diameter.

Since the reamer heads are available in a large range of sizes, please specify reamer diameter or mention the sizes of **cups** *or* **prostheses** *with which they are to be used.*

SPECIAL GROUP PRICE
Any three reaming heads, plus detachable shank, plus brace—$175.00 complete.

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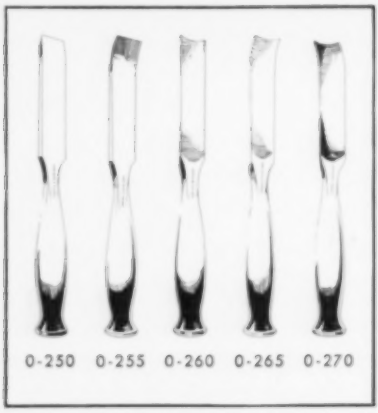

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A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES

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CASE 0-295—holds seven Smith-Petersen Osteotomes.

CASE 0-296—holds seven Smith-Petersen Gouges.

CASE 0-297—holds a combination of seven Osteotomes and Gouges.

Cutting edges are protected at all times. Complete unit may be autoclaved.

Specify Width of Gouges and Osteotomes When Ordering

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MOST POTENT ANTI-RHEUMATIC

Sterane*

Even where hydrocortisone, cortisone, and other agents had failed, prednisolone (STERANE) restored articular mobility and functional capacity to normal in rheumatoid arthritis.[1]

Four times more effective than hydrocortisone, and, on the basis of preliminary findings,[2,3] superior in potency even to prednisone (cortisone analog), STERANE is also relatively free of such hormonal side effects as edema, hypertension, or hypopotassemia.

Supplied: White, 5 mg. oral tablets, in bottles of 20 and 100. Pink, 1 mg. oral tablets, in bottles of 100. Both are deep-scored and in the distinctive "easy-to-break" size and Pfizer oval shape.

References: 1. Bunim, J. J., et al.: J.A.M.A. 157:311, 1955. 2. Forsham, P. H., et al.: Paper presented at First Internat. Conf. on Prednisone and Prednisolone, New York, May 31-June 1, 1955. 3. Periman, P. L., and Tolksdorf, S.: Scientific Exhibit presented at A.M.A. Annual Meet., Atlantic City, June 6-11, 1955.

PFIZER LABORATORIES Division, Chas. Pfizer & Co., Inc. Brooklyn 6, New York

*brand of prednisolone

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The Journal of
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MAJOR EXARTICULATIONS FOR MALIGNANT NEOPLASMS OF THE EXTREMITIES: INTERSCAPULOTHORACIC AMPUTATION, HIP-JOINT DISARTICULATION, AND INTERILIO-ABDOMINAL AMPUTATION

A Report of End Results in 228 Cases

BY GEORGE T. PACK, M.D., NEW YORK, N. Y.

From the Memorial Cancer Center, New York

Major amputations have seldom been considered classical or orthodox treatment for any histogenetic or regional variety of cancer, with the exception of bone sarcomata. The procedure is usually adopted as one of desperation after all other methods have failed. In the strict definitive sense, "cure" of a disease means the eradication of the ailment with preservation of the part which contains it. In the case of cancer, the only modality which has ever been able to accomplish this objective has been irradiation with x-rays and radium; after such treatment the organ or tissue is retained, although it is usually damaged to some degree. When a cancer on an extremity, originating in skin, bone, cartilage, or soft somatic tissue, becomes otherwise uncontrollable, the common practice is to

TABLE I

General Types of Tumor for which Major Amputations Were Performed

Type of Tumor	Interscapulothoracic Amputation (*Per cent*)	Hip-Joint Disarticulation (*Per cent*)	Hemipelvectomy (*Per cent*)
Total	100.0	99.9	100.0
Skin	37.5	45.7	23.9
Soft somatic tissues	53.4	43.6	56.5
Bone	9.1	10.6	19.6

divorce the patient from this extremity and thereby remove the malignant tumor. The frequent failure of amputation to achieve the long-term survival of the patient may be attributed to two factors: (a) the inherent natural history of the cancer and (b) procrastination in performing the major amputation due to reluctance on the part of both patient and physician.

Interscapulothoracic amputation, hip-joint disarticulation, and interilio-abdominal amputation (hemipelvectomy) are done most commonly for soft-part sarcomata, next most commonly for malignant tumors of the skin, and least frequently for bone sarcomata (Tables I and II). This order of frequency does not follow the natural order of frequency of the neoplasms; as is well known, skin cancers (epitheliomata and melanomata) are the most common neoplasms, while soft-tissue sarcomata are the next most frequent and

TABLE II

RADICAL SURGERY OF THE EXTREMITIES: INCIDENCE ACCORDING TO HISTOLOGIC TYPE OF TUMOR

Histologic Type of Tumor	Interscapulothoracic Amputation		Hip-Joint Disarticulation		Hemipelvectomy	
	(*No.*)	(*Per cent*)	(*No.*)	(*Per cent*)	(*No.*)	(*Per cent*)
Total cases	88	100.0	94	99.9	46	100.0
Tumors of skin, primary in the extremity	26	29.5	43	45.7	11	23.9
Melanoma	20	22.7	41	43.6	8	17.4
Carcinoma	6	6.8	2	2.1	3	6.5
Tumors of skin, primary elsewhere	7	8.0	0	0.0	0	0.0
Melanoma	2	2.2	0	0.0	0	0.0
Carcinoma	5	5.7	0	0.0	0	0.0
Tumors of soft somatic tissues, primary in the extremity	47	53.4	41	43.6	26	56.5
Rhabdomyosarcoma	14	15.9	5	5.3	5	10.9
Fibrosarcoma	8	9.1	5	5.3	3	6.5
Synovioma	7	8.0	5	5.3	2	4.3
Sarcoma unclassified	6	6.8	15	16.0	1	2.2
Malignant neurilemoma	5	5.7	7	7.4	4	8.7
Angiosarcoma	4	4.5	0	0.0	0	0.0
Liposarcoma	1	1.1	3	3.2	5	10.9
Reticulum-cell sarcoma	1	1.1	1	1.1	0	0.0
Dermatofibrosarcoma protuberans	0	0.0	0	0.0	3	6.5
Kaposi's sarcoma	0	0.0	0	0.0	1	2.2
Extra-osseous osteogenic sarcoma	0	0.0	0	0.0	1	2.2
Alveolar soft-tissue sarcoma	0	0.0	0	0.0	1	2.2
Extra-abdominal desmoid	1	1.1	0	0.0	0	0.0
Tumors of bone, primary in the extremity	8	9.1	10	10.6	9	19.6
Osteogenic sarcoma	3	3.4	4	4.3	2	4.3
Chondrosarcoma	2	2.3	3	3.2	6	13.0
Endothelial myeloma	1	1.1	2	2.1	0	0.0
Periosteal fibrosarcoma	0	0.0	1	1.1	1	2.2
Neuroblastoma	1	1.1	0	0.0	0	0.0
Reticulum-cell sarcoma	1	1.1	0	0.0	0	0.0

malignant bone tumors are the least frequent. Lesser surgical measures suffice for most malignant tumors of the skin and soft somatic tissues. A comparison of the number of major amputations performed for each group of neoplasms with the incidence of occurrence of the groups shows that patients with bone sarcomata lose an extremity proportionately more often than do patients with the other types of tumor; patients with somatic-tissue sarcomata are next in order, and last in order are patients with malignant skin tumors. The age of our patients who suffered amputation of an extremity varied from thirteen months to seventy-nine years (Table III).

Associated Nodal Dissections

Associated nodal dissections above the level of amputation are indicated for certain maligant tumors. The axillary or inguinal lymph nodes may be so massive and fixed as to constitute prime indicators for forequarter and hindquarter amputations. In association with interscapulothoracic amputations we frequently perform radical cervical lymph-node dissection; and in association with hip-joint disarticulations we frequently perform retroperitoneal iliac and obturator nodal dissection. These associated dissections are done not only when the nodes are palpable but even when the nodes are impalpable but are suspected. It appears that nodal dissections conjoined with amputation are more commonly necessary in patients with the following cancers: (a) metastatic melanoma of the extremi-

TABLE III

RADICAL SURGERY OF THE EXTREMITIES (SEX AND RANGE IN AGE OF PATIENTS)

Type of Tumor	Interscapulothoracic Amputation			
	Total	Male	Female	Range in Age
Total cases	88	50	38	13 months to 79 years
Tumors of skin	33	14	19	26 years to 74 years
Tumors of soft somatic tissues	47	33	14	13 months to 79 years
Tumors of bone	8	3	5	11 years to 67 years

Type of Tumor	Hip-Joint Disarticulation			
	Total	Male	Female	Range in Age
Total cases	94	45	49	3 years to 72 years
Tumors of skin	43	19	24	16 years to 65 years
Tumors of soft somatic tissues	41	21	20	3 years to 72 years
Tumors of bone	10	5	5	7 years to 62 years

Type of Tumor	Hemipelvectomy			
	Total	Male	Female	Range in Age
Total cases	46	26	20	15 years to 61 years
Tumors of skin	11	6	5	21 years to 53 years
Tumors of soft somatic tissues	26	14	12	15 years to 61 years
Tumors of bone	9	6	3	34 years to 60 years

ties, (b) metastatic epidermoid carcinoma of the extremities, (c) malignant synovioma (this tumor is common on the hands and feet and metastasizes to the regional nodes in 18 to 20 per cent of cases), (d) fibrosarcoma and rhabdomyosarcoma (these tumors spread to the nodes in only 3 to 4 per cent of our patients), (e) reticulum-cell sarcoma.

Because it originates in lymphoid tissue, the superior lymph node may contain metastatic relays of an upward dissemination, and it is a wise precaution to perform dissection of this node on the assumption that such relays are present. It is not generally known that reticulum-cell sarcomata sometimes invade muscles, where they acquire a surprising resistance to x-rays.

Palliation

One should not be too critical in evaluating the curability achieved by these operations, as recorded in Tables IV, V, and VI. Many of the amputations were done with the original and sole intent of palliation. Their value, therefore, cannot be measured by their rate of cure alone. By definition palliation does not mean that the patient should live longer and suffer more but rather that the remaining months and years of his life should be spent in comfortable living with lessened disability. There is no method of determining the value of these operations for achieving short-term survivals. The operations have been done upon patients with known pulmonary metastases if the metastases were few, small, and asymptomatic. In a patient with Kaposi's idiopathic hemorrhagic sarcoma involving both lower extremities (one slightly and the other completely), one limb was ulcerated, fungating, enormously swollen, and so fetid as to be almost intolerable even to the bedridden patient. A palliative hemipelvectomy removed this disability, enabled him to become ambulatory, made him an acceptable member of his household, lessened

TABLE IV

TYPE OF TUMOR AND END RESULTS FOLLOWING INTERSCAPULOTHORACIC AMPUTATION FOR TUMORS PRIMARY IN THE EXTREMITY

Type of Malignant Tumor	Total Cases	Patients Who Have Died			Patients Who Are Living				
		Total Cases	With Cancer	Without Cancer	Total Cases	With Cancer	Without Cancer		
							Under 5 Years	5–10 Years	Over 10 Years
Total cases	81	53 ***	47	3	28	4	11	8	5
Tumors of soft somatic tissues—total	47	29 **	25	2	18	2	5	6	5
Rhabdomyosarcoma	14	11 *	10	0	3	0	2	0	1
Fibrosarcoma	8	2	1	1	6	1	1	3	1
Synovioma	7	5	5	0	2	1	0	1	0
Sarcoma unclassified	6	5	4	1	1	0	0	0	1
Malignant neurilemoma	5	3 *	2	0	2	0	0	0	2
Angiosarcoma	4	3	3	0	1	0	0	1	0
Reticulum-cell sarcoma	1	0	0	0	1	0	0	1	0
Liposarcoma	1	0	0	0	1	0	1	0	0
Extra-abdominal desmoid tumor	1	0	0	0	1	0	1	0	0
Tumors of skin—total	26	19 *	17	1	7	2	3	2	0
Melanoma	20	15 *	14	0	5	1	3	1	0
Carcinoma	6	4	3	1	2	1	0	1	0
Tumors of bone—total	8	5	5	0	3	0	3	0	0
Osteogenic sarcoma	3	2	2	0	1	0	1	0	0
Chondrosarcoma (2), neuroblastoma (1)	3	3	3	0	0	0	0	0	0
Reticulum-cell sarcoma (1), endothelial myeloma (1)	2	0	0	0	2	0	2	0	0

* Includes one case in which the cause of death was not known.
** Includes two cases in which the cause of death was not known.
*** Includes three cases in which the cause of death was not known.

TABLE V

TYPE OF TUMOR AND END RESULTS FOLLOWING HIP-JOINT DISARTICULATION

Type of Malignant Tumor	Total Cases	Patients Who Have Died			Patients Who Are Living				
		Total Cases	With Cancer	Without Cancer	Total Cases	With Cancer	Without Cancer		
							Under 5 Years	5–10 Years	Over 10 Years
Total cases	94 **	61	59	2	30	2	20	6	2
Tumors of skin—total	43 *	26	25	1	16	2	10	4	0
Melanoma	41 *	25	24	1	15	2	10	3	0
Carcinoma	2	1	1	0	1	0	0	1	0
Tumors of soft somatic tissues—total	41 *	31	30	1	9	0	5	2	2
Sarcoma unclassified	15	14	14	0	1	0	1	0	0
Malignant neurilemoma	7	4	3	1	3	0	1	0	2
Rhabdomyosarcoma	5 *	3	3	0	1	0	1	0	0
Fibrosarcoma	5	2	2	0	3	0	2	1	0
Synovioma	5	5	5	0	0	0	0	0	0
Liposarcoma	3	2	2	0	1	0	0	1	0
Reticulum-cell sarcoma	1	1	1	0	0	0	0	0	0
Tumors of bone—total	10 *	4	4	0	5	0	5	0	0
Osteogenic sarcoma	4 *	1	1	0	2	0	2	0	0
Chondrosarcoma	3	1	1	0	2	0	2	0	0
Endothelial myeloma	2	2	2	0	0	0	0	0	0
Periosteal fibrosarcoma	1	0	0	0	1	0	1	0	0

* One patient was lost to follow-up.

** Three patients were lost to follow-up.

TABLE VI

TYPE OF TUMOR AND END RESULTS FOLLOWING HEMIPELVECTOMY

Type of Malignant Tumor	Total Cases	Patients Who Have Died			Patients Who Are Living				
		Total Cases	With Cancer	Without Cancer	Total Cases	With Cancer	Without Cancer		
							Under 5 Years	5–10 Years	Over 10 Years
Total cases	46 [1]	28 [2]	26	0	15	2	10	3	0
Tumors of skin—total	11	8	8	0	3	1	2	0	0
Melanoma	8	6	6	0	2	1	1	0	0
Carcinoma	3	2	2	0	1	0	1	0	0
Tumors of soft somatic tissues—total	26 [3]	15 [4]	14	0	9	1	7	1	0
Liposarcoma	5 [5]	2	2	0	2	0	1	1	0
Rhabdomyosarcoma	5	3	3	0	2	0	2	0	0
Malignant neurilemoma	4 [5]	3	3	0	0	0	0	0	0
Fibrosarcoma	3	1	1	0	2	1	1	0	0
Dermatofibrosarcoma protuberans	3	2	2	0	1	0	1	0	0
Synovioma	2	1	1	0	1	0	1	0	0
Kaposi's sarcoma	1	1	1	0	0	0	0	0	0
Extra-osseous osteogenic sarcoma	1	1 [4]	0	0	0	0	0	0	0
Alveolar soft-part sarcoma	1	0	0	0	1	0	1	0	0
Sarcoma unclassified	1	1	1	0	0	0	0	0	0
Tumors of bone—total	9 [5]	5 [4]	4	0	3	0	1	2	0
Chondrosarcoma	6 [5]	2	2	0	3	0	1	2	0
Osteogenic sarcoma	2	2	2	0	0	0	0	0	0
Periosteal fibrosarcoma	1	1 [4]	0	0	0	0	0	0	0

[1] Three cases were lost to follow-up.
[2] In two cases, death was due to other causes.
[3] Two cases were lost to follow-up.
[4] In one case death was due to other causes.
[5] One case was lost to follow-up.

TABLE VII

FIVE-YEAR END RESULTS FOLLOWING INTERSCAPULOTHORACIC AMPUTATION FOR TUMORS PRIMARY IN THE EXTREMITY IN RELATION TO METASTASIS FOUND AT OPERATION

End Result	All Cases			Tumors of Skin			Tumors of Soft Somatic Tissues			Tumors of Bone		
	All Cases	Metastasis Present	Metastasis Absent	All Cases	Metastasis Present	Metastasis Absent	All Cases	Metastasis Present	Metastasis Absent	All Cases	Metastasis Present	Metastasis Absent
Determinate cases	39	14	25	9	7	2	28	6	22	2	1	1
Failures—died with disease	26	12	14	7	7	0	17	4	13	2	1	1
Successful results: living without disease	13	2	11	2	0	2	11	2	9	0	0	0

TABLE VIII

FIVE-YEAR END RESULTS FOLLOWING RADICAL SURGERY ON THE LOWER EXTREMITY IN RELATION TO METASTASIS FOUND AT OPERATION

End Result	All Cases			Tumors of Skin			Tumors of Soft Somatic Tissues			Tumors of Bone		
	All Cases	Metastasis Present	Metastasis Absent	All Cases	Metastasis Present	Metastasis Absent	All Cases	Metastasis Present	Metastasis Absent	All Cases	Metastasis Present	Metastasis Absent
Hip-joint disarticulation:												
Determinate cases, 1926–1948	52	24	28	18	15	3	30	7	23	4	2	2
Failures *	44	20	24	14	12	2	26	6	20	4	2	2
Successful results **	8 [1]	4	4 [1]	4 [1]	3	1 [1]	4	1	3	0	0	0
Hemipelvectomy:												
Determinate cases, 1944–1948	14	5	9	0	0	0	10	5	5	4	0	4
Failures	11 [2]	5	6 [2]	0	0	0	9 [2]	5	4 [2]	2	0	2
Successful results	3	0	3	0	0	0	1	0	1	2	0	2

* Failures—died with cancer under five years unless specified.

** Successful results—living five years or more without cancer unless specified.

[1] One patient survived five years without cancer and died of other causes.

[2] One patient is living with cancer after less than five years.

TABLE IX

END RESULTS OF INTERSCAPULOTHORACIC AMPUTATION FOR METASTATIC TUMORS WITH PRIMARY SITE NOT IN THE EXTREMITY

Sex	Age	Primary Tumor		Metastatic Tumor		Date of Radical Surgery	End Results
		Location	Histological Type	Location	Previous Treatment		
M	57	Choroid	Melanoma	Arm	Excision	9–3–41	Died with cancer 5 months
F	42	Breast	Adeno-carcinoma	Supra-clavicular region	Irradiation	4–27–49	Died with cancer 8 months
F	43	Breast	Adeno-carcinoma	Axilla	None	4–22–49	Died with cancer 10 months
F	45	Colon	Adeno-carcinoma	Axilla	Excision 2 axillary dissections	5–28–51	Died with cancer 22 months
F	33	Not known	Melanoma	Axilla	Excision	8–23–51	Lost to follow-up soon after operation
M	55	Alveolar ridge	Squamous carcinoma	Shoulder	None	12–10–51	Died in 12 months from perforated gastric ulcer. No evidence of cancer at that time
F	61	Breast	Adeno-carcinoma	Arm	None	5–28–52	Living 14 months postoperatively with metastases to spine

the burdensome cost of medical and nursing care, and gave him an additional eighteen months of life.

Causes of Failure after Major Exarticulations

An analytical survey of our 228 amputations reveals certain causes of failure.

1. If the primary cancer was situated elsewhere than in the amputated extremity, the result could only be palliative (seven cases).

2. Borderline operability of the malignant tumor: too often these amputations were operations of desperation, employed only when all other methods had failed.

3. As may be seen in Tables XVI, XVII, and XVIII, many of the exarticulations were performed for recurrent cancer. Our end results demonstrated that the prognosis for patients operated upon for recurrent cancer is 12 to 45 per cent inferior to the prognosis for patients in whom the same operations are applied as primary or initial treatment.

4. Recurrence in the stump: tumors which extend insidiously upward along fascial and intermuscular planes and along the nerve sheaths may recur in the stump even after the highest amputations; such tumors as fibrosarcoma, synovioma, and neurilemoma frequently behave in this manner. Chondrosarcomata seldom recur locally after forequarter amputations but, when originating in the os innominatum, may recur in the pubis or sacrum after hemipelvectomy. Malignant melanomata often diffusely invade the stump by lymphatic permeation.

5. Distant metastases (Tables VII and VIII): metastases to the lungs are detected sometimes months or years after the operation, especially in patients with osteosarcoma, rhabdomyosarcoma, malignant synovioma, melanoma, and liposarcoma. The liposarcomata and melanomata not infrequently metastasize to the heart and brain.

In a previous survey of the end results following treatment of sarcomata of the soft somatic tissues [1], the strange paradox was related that local surgical dissection gave a much higher rate of cure than did amputation. The explanation resided in the fact that

TABLE X

FIVE-YEAR END RESULTS FOLLOWING INTERSCAPULOTHORACIC AMPUTATION FOR MALIGNANT TUMORS PRIMARY IN THE EXTREMITY

End Results	All Cases	Tumors of Skin	Tumors of Soft Somatic Tissues	Tumors of Bone
All cases, 1926 through 1953	84	26	47	8
Indeterminate cases—total	6	2	4	0
Cause of death not known	3	1	2	0
Died of other causes	3	1	2	0
Determinate cases, 1926 through 1953	75	24	43	8
Determinate cases, 1949 through 1953	36	15	15	6
Determinate cases, 1926 through 1948, for evaluating five-year cure-rate	39	9	28	2
Failures: died with cancer	26	7	17	2
Successful results: living without cancer over 5 years	13	2	11	0
End results Successful results divided by the determinate cases, 1926 through 1948	13/39 33.3 per cent	2/9 22.2 per cent	11/28 39.3 per cent	None

surgical dissection alone, although conservative, was an adequate operation for early sarcomata, whereas even a major amputation, although radical, was too often inadequate for extensive, recurrent, and metastatic sarcomata.

For the specific types of tumor, the causes of postamputation failure were as follows.

Osteosarcoma: Pulmonary metastasis, usually early, caused failures.

Malignant synovioma: There were distant metastases to the lungs and soft tissues.

Endothelial myeloma: Pulmonary metastasis with multiple bone involvement caused failures.

Angiosarcoma: This tumor is of multicentric origin, and ultimate generalization occurred as in Kaposi's hemorrhagic sarcoma and as in lymphangiosarcoma developing in elephantiasis chirurgica.

Chondrosarcoma: There was local recurrence in the sacrum or pubis after hemipelvectomy and also pulmonary metastasis.

Malignant Neurilemoma: Proximal recurrence in the moniliform beading of severed nerve trunks occurred; the new tumors seemed to develop centripetally. In patients with this tumor, it is most essential to sever the nerve plexuses as high as possible.

Rhabdomyosarcoma: If the upper portions of the arm or thigh are involved, interscapulothoracic amputation or hemipelvectomy is indicated rather than shoulder or hip-joint disarticulation in keeping with the principle that amputation should be above the level of origin of the muscles involved.

Malignant melanoma: Bone and visceral involvement (lungs, liver, brain, heart) occurred. Skin recurrences in the stump and extension into superior groups of lymph nodes, pre-aortic, cervical, mediastinal, also occurred.

Fibrosarcoma: Patients with this tumor may have desmoplastic diathesis. A liberal superior margin must be allowed in amputations for this tumor. Case records in this series recite instances of origin of this tumor on hands or feet with proximal growth by continuity until intrathoracic or intra-abdominal extension had been obtained.

TABLE XI

FIVE-YEAR END RESULTS FOLLOWING HIP-JOINT DISARTICULATION

End Results	All Cases	Tumors of Skin	Tumors of Soft Somatic Tissues	Tumors of Bone
All cases, 1926 through 1953	94	43	41	10
Indeterminate cases—total	4	1	2	1
3 patients lost to follow-up and 1 patient died of other causes after less than five years				
Determinate cases, 1926 through 1953	90	42	39	9
Determinate cases, 1949 through 1953	38	24	9	5
Determinate cases, 1926 through 1948, for evaluating five-year cure-rate	52	18	30	4
Failures: Died with cancer	44	14	26	4
Successful results—total	8	4	4	0
Survived over five years without cancer, died of other causes	1	1	0	0
Living without cancer	7	3	4	0
End results				
Successful results divided by determinate cases, 1926 through 1948	8/52 15.4 per cent	4/18 22.2 per cent	4/30 13.3 per cent	None

TABLE XII

FIVE-YEAR END RESULTS FOLLOWING HEMIPELVECTOMY

End Results	All Cases	Tumors of Skin	Tumors of Soft Somatic Tissues	Tumors of Bone
All cases, 1944 through 1953	46	11	26	9
Indeterminate cases—total	5	0	3	2
Lost to follow-up	3	0	2	1
Died of other causes	2	0	1	1
Determinate cases, 1944 through 1953	41	11	23	7
Determinate cases, 1949 through 1953	27	11	13	3
Determinate cases, 1944 through 1948, for evaluating five-year cure-rate	14	0	10	4
Failures—total	11	0	9	2
Died as a result of cancer	10	0	8	2
Living with cancer	1	0	1	0
Successful results: living without cancer over five years	3	0	1	2
End results				
Successful results divided by the determinate cases 1944 through 1948	3/14 21.4 per cent	None	1/10 10 per cent	2/4 50. per cent

TABLE XIII

PATIENTS SURVIVING FIVE YEARS OR MORE WITHOUT CANCER FOLLOWING INTERSCAPULOTHORACIC AMPUTATION

Sex	Age	Previous Treatment	Location of Primary Tumor	Date of Operation	Histological Type of Tumor	Living Without Cancer
M	24	3 local excisions 3 amputations and axillary dissection	Forearm	2–25–35	Malignant neurilemoma	20 years
M	34	Irradiation	Arm	3–2–38	Neurofibrosarcoma	17 years
M	47	2 local excisions Irradiation	Axilla	9–27–39	Paraganglioma	15 years, 6 months
M	30	4 local excisions Irradiation	Arm	11–8–39	Sarcoma unclassified	14 years
F	48	Local excision Irradiation	Arm	4–7–41	Rhabdomyosarcoma	14 years
F	43	2 local excisions	Axilla	10–31–41	Fibrosarcoma	Over 9 years
F	28	None	Shoulder	2–21–45	Synovioma	10 years
M	10	None	Axilla	5–14–45	Fibrosarcoma	10 years
F	27	2 local excisions	Infraclavicular region	3–11–46	Fibrosarcoma	9 years
M	21	Local excision	Arm	9–10–46	Reticulum-cell sarcoma	8 years, 5 months
F	57	3 local excisions Irradiation	Axilla	8–18–47	Basal-cell carcinoma	7 years, 4 months
M	47	Local excision Irradiation	Axilla	9–3–47	Melanoma	7 years, 5 months
M	14	Local excision	Axilla	11–28–47	Angio-endothelioma	7 years, 4 months

TABLE XIV

PATIENTS SURVIVING FIVE YEARS OR MORE WITHOUT CANCER FOLLOWING HIP-JOINT DISARTICULATION

Sex	Age	Previous Treatment	Location of Primary Tumor	Date of Operation	Histological Type of Tumor	End Results
F	19	4 local excisions Amputation of first toe	First toe	1–28–31	Malignant neurilemoma	Living without evidence of cancer—24 years
M	59	2 local excisions	Thigh	5–23–31	Malignant neurilemoma	Lived over 15 years without evidence of cancer, then lost to follow-up
M	61	None	Subungual, great toe	2–14–46	Melanoma	Lived 5 years and 2 months without evidence of cancer. Died of other causes
F	55	None	Thigh	6–17–46	Fibrosarcoma	Living without evidence of cancer—8 years and 9 months
F	39	3 local excisions Mid-thigh amputation	Thigh	1–24–47	Myxoliposarcoma	Living without evidence of cancer—8 years
M	37	2 local excisions	Leg	7–21–47	Melanoma	Living without evidence of cancer—7 years and 9 months
M	32	Amputation Irradiation	Leg	1–23–48	Squamous carcinoma	Living without evidence of cancer—7 years
M	38	Excision	Leg	10–18–48	Melanoma	Living without evidence of cancer—6 years and 5 months

TABLE XV

PATIENTS SURVIVING FIVE YEARS OR MORE WITHOUT CANCER FOLLOWING HEMIPELVECTOMY

Sex	Age	Previous Treatment	Location of Primary Tumor	Date of Operation	Histological Type of Tumor	Living Without Cancer
M	60	None	Right ischium and pubis	1-9-45	Chondrosarcoma	10 years
M	40	Excision	Thigh and groin	1-14-46	Myxoliposarcoma	9 years
M	45	3 excisions Amputation Irradiation	Femur	3-4-47	Chondrosarcoma	8 years

Determinate Five-Year Cures

In a breakdown of the figures for patients treated more than five years previously (Tables X, XI, and XII), it was found that the cure rates for the three major types of amputation were: hip-joint disarticulation—15.4 per cent, interscapulothoracic amputation—33.3 per cent, and hemipelvectomy—21.4 per cent. For malignant skin tumors the five-year cure rates following hip-joint disarticulation, interscapulothoracic amputation, and hemipelvectomy were 22.2 per cent, 22.2 per cent, and 0, respectively; for soft-part sarcomata, 13.3 per cent, 39.3 per cent, and 10 per cent, respectively; for bone sarcomata, 0, 0, and 50 per cent, respectively. Nine of our patients are living and well over ten years after major exarticulations. We have been doing interilio-abdominal amputations for ten years, and our first patient to undergo this procedure (chondrosarcoma) is still living and well. Two patients are well twenty years after an interscapulothoracic amputation and a hip-joint disarticulation respectively.

The details as to cure for the various malignant tumors are as follows (Tables IV, V, and VI and Tables XIII, XIV, and XV):

Malignant melanoma—primary on the extremity. Of sixty-nine patients, four have survived over five years without evidence of cancer; in three of these patients hip-joint disarticulations were performed, and in one an interscapulothoracic amputation was performed.

Carcinoma—primary on the extremity. Of eleven patients, two are living and well

TABLE XVI

PREVIOUS TREATMENT IN RELATION TO END RESULTS AFTER INTERSCAPULOTHORACIC AMPUTATION FOR TUMORS PRIMARY IN THE EXTREMITY

Type of Previous Treatment	All Cases			Tumors of Skin			Tumors of Soft Somatic Tissues			Tumors of Bone		
	Total	Died	Living	Total	Died	Living	Total	Died	Living	Total	Died	Living
All cases	81	53	28	26	19	7	47	29	18	8	5	3
No previous treatment	19	12	7	4	4	0	11	6	5	4	2	2
Irradiation only	5	4	1	1	1	0	4	3	1	0	0	0
Excision [1]	38	25	13	13	9	4	22	14	8	3	2	1
Dissection [2]	8	4	4	4	2	2	4	2	2	0	0	0
Amputation [3]	11	8	3	4	3	1	6	4	2	1	1	0

[1] In 22 instances, excision only; in the others irradiation also.

[2] In 6 instances, excision also; in the others, irradiation had also been employed.

[3] In 3 instances, amputation only; in the others, various combinations of the other procedures listed above had also been employed.

after more than five years, one following hip-joint disarticulation and one following interscapulothoracic amputation.

Reticulum-cell sarcoma. Of two patients, one has been living and well after forequarter resection for over eight years. This proportion of cures (50 per cent) is unusual in view of the tendency of this tumor to become generalized.

Malignant neurilemoma. Five of the sixteen exarticulations resulted in five-year cures (31 per cent). Four of these five patients are well after more than ten years.

Chondrosarcoma. Of the eleven patients undergoing amputation, five are living; of these, two have been well over five years, both having undergone hemipelvectomy.

TABLE XVII

PREVIOUS TREATMENT IN RELATION TO END RESULTS AFTER HIP-JOINT DISARTICULATION (1925 THROUGH 1953)

Type of Previous Treatment	All Cases			Tumors of Skin			Tumors of Soft Somatic Tissues			Tumors of Bone		
	Total	Died	Living	Total	Died	Living	Total	Died	Living	Total	Died	Living
All cases	94 [1]	60	31	43 [2]	25	16	41 [2]	30	10	10 [2]	4	5
No previous treatment	19 [2]	10	8	7	5	2	7	5	2	5 [2]	0	4
Irradiation only	6	5	1	0	0	0	4	3	1	2	2	0
Excision [3]	43 [2]	30	12	14	7	7	25 [2]	21	4	3	2	1
Dissection [4]	11	7	4	10	6	4	1	1	0	0	0	0
Amputation [5]	15 [2]	8	6	12 [2]	8	3	3	0	3	0	0	0

[1] Three cases were lost to follow-up.
[2] One case was lost to follow-up.
[3] In 29 instances, excision only; in 14 irradiation also used.
[4] In 2 instances, dissection only; in the others, excision with or without irradiation.
[5] In 6 instances, amputation only; in the others various combinations of the previously mentioned procedures were used.

TABLE XVIII

PREVIOUS TREATMENT IN RELATION TO END RESULTS AFTER HEMIPELVECTOMY (1944 THROUGH 1953)

Type of Previous Treatment	All Cases			Tumors of Skin			Tumors of Soft Somatic Tissues			Tumors of Bone		
	Total	Died	Living	Total	Died	Living	Total	Died	Living	Total	Died	Living
All cases	46 [1]	28	15	11	8	3	25 [2]	15	9	9 [2]	5	3
No previous treatment	12	7	5	1	1	0	6	3	3	5	3	2
Irradiation only	1	1	0	0	0	0	1	1	0	0	0	0
Excision [4]	21 [2]	13	6	3	2	1	15 [3]	9	5	3 [3]	2	0
Dissection [5]	5 [3]	2	2	3	1	2	2 [3]	1	0	0	0	0
Amputation [6]	7	5	2	4	4	0	2	1	1	1	0	1

[1] Three cases were lost to follow-up.
[2] Two cases were lost to follow-up.
[3] One case was lost to follow-up.
[4] In 3 instances, irradiation was also employed.
[5] In 4 instances, excision was also performed, in the other excision and irradiation.
[6] In one instance, amputation only; in the others, various combinations of the other procedures were also used.

Osteogenic sarcoma. Of nine patients, three have been living and well for less than five years.

Rhabdomyosarcoma. Of twenty-four patients six are living and well. Five of these have been well less than five years; one has been well more than ten years.

Angiosarcoma. Of five patients, one has been living and well more than five years.

Malignant synovioma. Fourteen patients were operated on and two are living and well, one for more than five years.

Skin cancers—primary site elsewhere than on an extremity. Seven patients were operated on, and none were cured. The average postoperative length of life was twelve months. Three patients with breast cancers had interscapulothoracic amputations in conjunction with radical mastectomy. One patient who required amputation for metastatic colonic cancer survived for twenty-two months.

Influence of Previous Unsuccessful Treatment on the End Results of Exarticulation

Previous therapy by surgical dissection, irradiation, or lesser amputation unfavorably influences the results achieved by major amputation (see Tables XVI, XVII, and XVIII). In our series the results of major amputations for residual cancers in patients surviving previous treatment as compared with the results of the same procedures for primary untreated cancers were inferior by 12 per cent (interscapulothoracic amputation), by 40 per cent (hip-joint disarticulation), and 45 per cent (hemipelvectomy). Of patients undergoing interscapulothoracic amputation, 37 per cent of those having no previous treatment and 34 per cent of those having recurrent or residual cancers are living and well at present. Of patients undergoing hip-joint disarticulation, 42 per cent of those having no previous treatment and 31 per cent of those having recurrent or residual cancers are now living and well; and of patients undergoing hemipelvectomy, 42 per cent of those having no previous treatment and 29 per cent of those having recurrent or residual cancers, are living and well.

Operative Mortality

There were no operative deaths as the result of the 228 major exarticulations.

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Circumduction Fusion of the Spine *

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This is a report on the results of fusion of the spine in a series of seventeen patients with mid-line infection or defects which prevented routine surgical approach. To secure ankylosis and stabilize the spine, it was necessary to construct a fusion beginning at the spine above the defect, extending laterally on ribs or transverse processes, and returning back to the spine below the defect (Fig. 1). The procedure, first done in 1946, has been described[1, 2]. The results will be recorded here.

Statistics

There were eleven males and six females. Nine were white and eight colored. Their ages ranged from nine to fifty-one years, with an average of thirty-three years. Fourteen had tuberculosis of the spine. Three did not. These three were patients who had undergone laminectomy and facetectomy causing marked instability of the spine and severe disability.

Twenty-nine operations were performed on these seventeen patients in the attempt to secure continuity of the circumduction fusion around the affected spinal areas. Four patients required three procedures, four required two procedures, and nine fusions were performed in a single stage. Twelve additional mid-line spinal fusions were done on these patients outside the area of the circumduction fusion in the treatment of their spinal disease.

Areas Involved

In thirteen of the patients the fusion was in the thoracic or thoracolumbar area. These were all patients with tuberculosis of the spine. In four instances, the fusion was in the lumbar area; three fusions extended to the sacrum. One of the four patients had tuberculosis of the spine. Three were patients who had severe instability of the spine resulting from wide laminectomy with removal of the articular processes. They were, before reparative surgery was attempted, completely

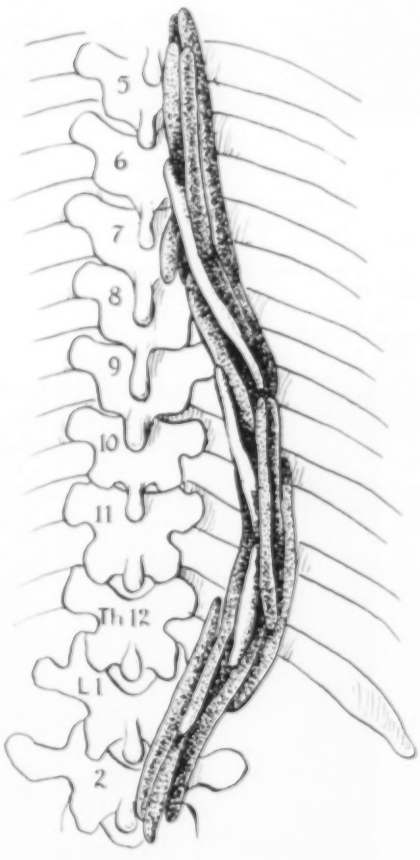

FIG. 1

Drawing shows the placing of strip iliac grafts in circumduction fusion.

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 21, 1955.

disabled and in considerable pain. The experience of these patients emphasizes the fact that wide laminectomy and facetectomy is not a procedure to be condoned. As one of our young associates has remarked, "better tuberculosis of the spine than an inept surgeon".

FIG. 2-A FIG. 2-B FIG. 2-C

Figs. 2-A through 2-F: When first seen this patient had an estimated 90 per cent paralysis from tuberculous involvement of the spine. Previous attempted mid-line fusion had failed. Sinuses in the incision proved positive for *Mycobacterium tuberculosis;* mixed organisms prevented further mid-line surgery. Circumduction fusion from the sixth thoracic to first lumbar vertebra was done. Additional mid-line fusions were done above to the third thoracic and below to the second lumbar vertebra.

Fig. 2-A: Anteroposterior roentgenogram. Right upper lung was collapsed on admission.

Fig. 2-B: Postero-anterior roentgenogram. Communication of posterior mid-line and right lumbar sinuses is shown.

Fig. 2-C: Circumduction fusion (oblique roentgenogram).

FIG. 2-D FIG. 2-E

Fig. 2-D: Final result.

Fig. 2-E: Healed sinuses and solid fusion. The patient recovered and is at regular work.

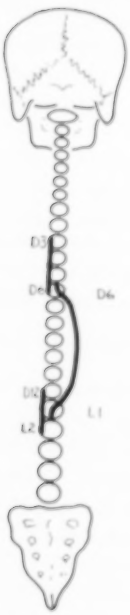

FIG. 2-F

Fig. 2-F: Diagram shows the extent of the circumduction fusion and the additional mid-line fusion above and below.

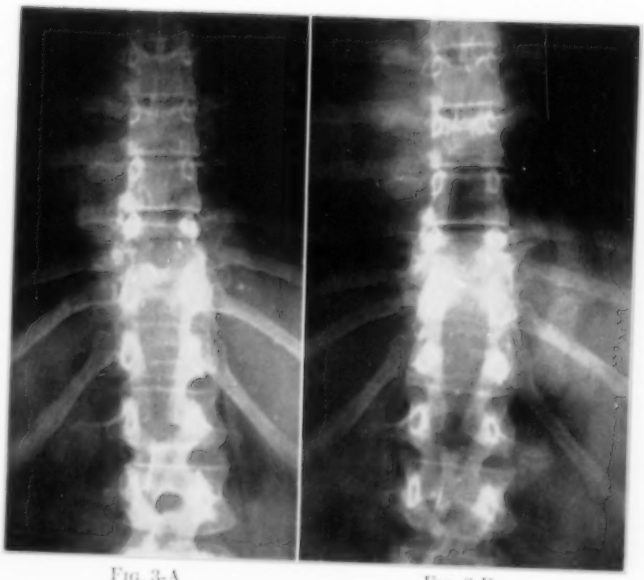

FIG. 3-A

FIG. 3-B

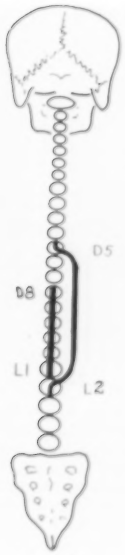

FIG. 3-C

Figs. 3-A, 3-B, and 3-C: This patient was totally paralyzed when admitted. Laminectomy previously had relieved pressure for three weeks only. The removal of the facets in the mid-area and upper area of the six-vertebra laminectomy left no bony attachment for mid-line fusion. Patient recovered completely following circumduction fusion and there were normal neurological findings and solid fusion. He is back at work.

Fig. 3-A: Condition on admission. Note wide laminectomy with removal of articular processes in the middle area and above.

Fig. 3-B: Circumduction fusion.

Fig. 3-C: Diagram shows extent of laminectomy and circumduction fusion.

Thoracic and Thoracolumbar Circumduction Fusions

Thirteen patients had circumduction fusion in the thoracic or thoracolumbar segments of the spine. They all had tuberculous involvement of the spine. The disease had existed before operation from six months to twenty-two years, with an average of four years and seven months. There were no deaths related to the spinal surgery, no major operative complications, and no postoperative wound infections.

Although in building a new spinal support by circumduction fusion the number of intervals covered is not as important as it is in the classical type of spine fusion, the areas are here recorded. The fusions were within the area from the sixth cervical vertebra to the fourth lumbar vertebra inclusively. The area of greatest extent covered was from the first thoracic vertebra to the second lumbar vertebra—fourteen segments. The shortest area in this series was from the eighth thoracic vertebra to the first lumbar vertebra—six segments. The average area covered was nine segments.

Solid fusion (Figs. 2-D, 2-E, and 2-F) throughout the area covered was secured in eleven of these thirteen patients.

Pseudarthrosis developed in two patients and these represent failures of complete fusion. All thirteen patients had tuberculous involvement of the spine, and their condition was precarious without other adverse factors. In addition to the tuberculous involvement, eleven had paraplegia. Seven had complete paraplegia. The estimate was that one had 90 per cent paraplegia, two had 50 per cent paraplegia, and one had 25 per cent paraplegia at the time circumduction fusion was performed.

In addition to the tuberculous involvement of the spine and the paraplegia, eight had had laminectomies. The most extensive laminectomy had involved six segments (Fig. 3-A). In addition to the adverse factors previously mentioned, five patients had mid-line

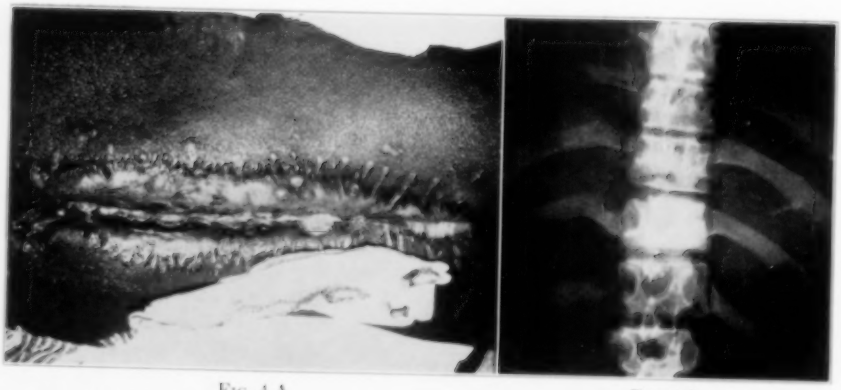

FIG. 4-A FIG. 4-B

Figs. 4-A through 4-E: This patient was totally paralyzed. Previous surgery resulted in wound disruption. Hemilaminectomy from the ninth to the twelfth thoracic vertebra had not relieved the paralysis. Sepsis had persisted for two years. Tuberculosis of the vertebral bodies and posterior elements was present. Mixed infection still existed in the mid-line below, where fusion attachment would be essential if the area causing the paralysis was to be stabilized. Circumduction fusion was done from the sixth thoracic to the second lumbar vertebra. It became solid and the patient recovered completely from paralysis and infection. He works as a laborer.

Fig. 4-A: The infected lumbar area.

Fig. 4-B: Note changes in the arches from ninth to twelfth thoracic vertebra and sclerosis of the body of the eleventh thoracic.

sinuses (Fig. 4-A) which, even without other complications, would prevent direct approach to the spine. In these, tuberculous involvement of the posterior bony elements of the spine was evident. There were many combinations of paraplegia, laminectomy defects, and sinus formation. Seven had paraplegia and laminectomy defects. Three of these had had mid-line sinuses in addition. One had paraplegia and sinuses. One had had a laminectomy and sinuses. Two had severe decubitus ulcers. Two suffered from large trophic sores over the trochanters. Six were emaciated. Two had hip tuberculosis, one had a tuberculous involvement of a knee and shoulder, one had tarsal disease, and one had tuberculosis of the scapula. To put it mildly, these were all sick patients.

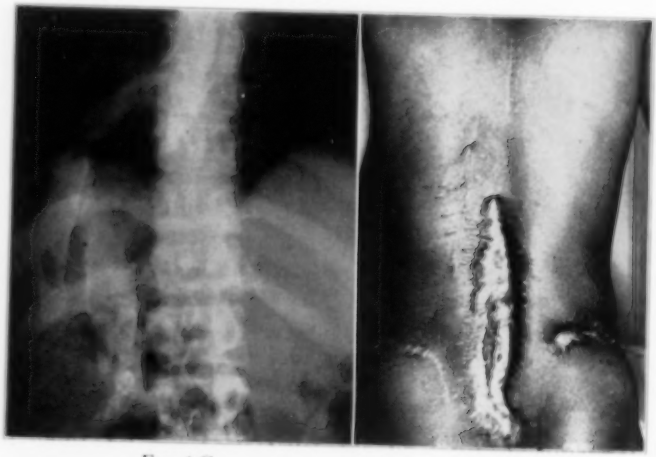

FIG. 4-C FIG. 4-D

FIG. 4-E

Fig. 4-C: Circumduction fusion.

Fig. 4-D: Diseased area has healed; patient is erect and has recovered.

Fig. 4-E: Diagram shows the circumduction fusion and laminectomy areas. The fusion in the lumbosacral area performed previously elsewhere is not shown.

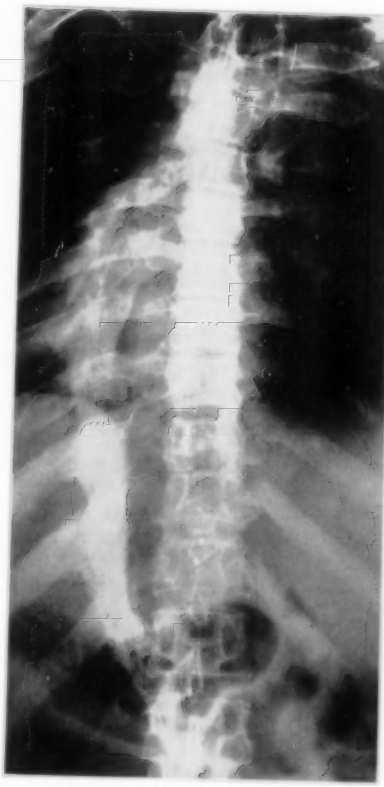

FIG. 5-A

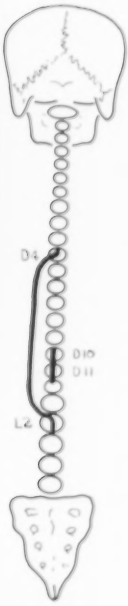

FIG. 5-B

Fig. 5-A: This patient had had a laminectomy in another hospital with temporary improvement and then relapse to total paraplegia. There was some pantopaque remaining after the myelogram had been made. The incision had been infected and had healed only after several months. The remaining posterior elements were not sufficient for graft attachment; oedematous tissues in the incision area did not encourage a second midline approach. Circumduction fusion was successfully accomplished; the patient recovered from paralysis and was discharged. He died as the result of an auto accident later. At the time of death, it was reported that he had additional disease beyond the area of the circumduction fusion; further fusion had been advised, which he had refused.

Fig. 5-B: Diagram shows the extent of the laminectomy and of the circumduction fusion.

The great extent of the fusion was due to extent of the abscess noted in roentgenograms of the thoracic spine.

Nine had had pantopaque myelograms and had considerable residual material in the dural sac. Four of these had pantopaque within the intracranial vault. One patient showed evidence of adhesive arachnoiditis associated with the retained pantopaque. It is amazing that all of these patients could have had dural punctures without subsequent meningitis.

Follow-up on these patients has been from three to nine years after operation, with an average of 4.1 years.

Results of Circumduction Fusion in the Thoracic and Thoracolumbar Area

Of these thirteen patients, twelve are still alive. This in itself is a major triumph when we review the condition of these unhappy patients when the treatment described was started. Of the twelve living patients, eleven are in good or excellent condition. One is still totally paraplegic. One patient (case shown in Fig. 5-A) died in an auto accident a year ago. His circumduction fusion was solid.

Ten are working. Seven of these ten are at regular full work and three do light work. Two are still disabled. In none was the fusion resorbed between points of contact with posterior bone. It has been noted that usually the fusion mass increased in size with time.

Eleven of the patients have been discharged, but one is still hospitalized. The sinuses of all of the patients who had sinuses have long since healed and have remained healed. This can be attributed to the circumduction fusion, to streptomycin and finally, in three instances, to iproniazid.

Of the eleven paraplegics, seven are totally recovered, two have recovered an estimated 75 per cent of their lost function, and one has recovered 50 per cent of function. One is still totally paraplegic. This last patient fractured his femur in bed and because of lack of pain sense, he compounded the fracture by twisting his leg in the sheets. Subsequent sepsis required amputation. His general physical condition remains good. His

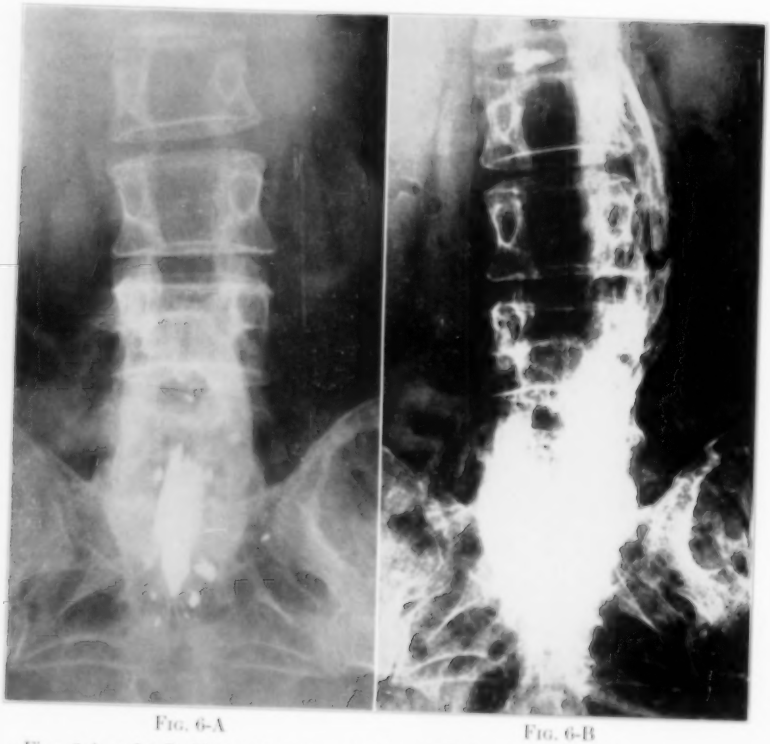

FIG. 6-A FIG. 6-B

Figs. 6-A and 6-B: This patient was totally disabled and was bedridden following a laminectomy-facetectomy between the second and third and the third and fourth lumbar vertebrae. A one-stage circumduction fusion on the transverse processes failed in this patient. Drug addiction and difficulty in controlling the patient prevented further hospitalization and operation by us. A patient with a similar condition whose fusion became solid recovered. Such patients may need several operations before sufficient bone is implanted to provide continuity of structure and strength of bony framework sufficient for support.

Fig. 6-A: Preoperative condition showing laminectomy-facetectomy of the second and third lumbar vertebrae. Note the residual pantopaque from myelogram procedure.

Fig. 6-B: Failure to secure continuity of circumduction fusion by a one-stage procedure is shown.

associated spinal sinuses were healed following iproniazid administration. He is still totally paralyzed and disabled. This was the only major postoperative complication occurring in the series.

Circumduction Fusion for Lumbar Lesions

Circumduction fusion in the lumbosacral area presents a different problem. Here, one has to depend on transverse processes instead of ribs for graft contact. Such fusions are essentially lateral fusions.

There were four patients who had circumduction fusion in the lumbar area placed from the spine above, out to the transverse processes and back to the spine or sacrum below, as a primary procedure. Three of these fusions were done in non-tuberculous patients in order to repair complete laminectomy and facetectomy defects. From our review of these patients and our knowledge of other similar cases, we would plead for the preservation of indispensable supporting structures.

One of these four patients had tuberculosis of the spine. She had a circumduction fusion in the lumbar region for mid-line sinuses. Her fusion became solid and she has totally recovered. She had no paraplegia. Her sinuses are healed.

All three of the patients who had had laminectomy and facetectomy were narcotic addicts at the time we admitted them. In one of these patients, a male, a solid circumduction fusion was secured. This patient recovered from his pain and was treated for and recovered from his addiction. Prolonged hospitalization incidental to securing solidity of the lateral fusion, and the patient's economic status, which prevented his escaping from our hospital ward, allowed a satisfactory period for removal from narcotics. Since removal from narcotics, he has been under our observation for three and a half years without tendency to revert to drug addiction.

In two patients for whom lateral fusion was attempted in order to repair laminectomy and facetectomy defects pseudarthroses developed. Their drug addiction was severe. They suffered from deep functional and psychic overlay. One was a compensation case and was removed for permanent institutionalization due to prolonged addiction and continued disability. Attempt at further repair of the pseudarthrosis has not been possible. This patient is totally disabled and is still an addict. A second (Figs. 6-A and 6-B) was transferred to another veterans' hospital (when Halloran Hospital was closed), was reoperated upon, and still had a pseudarthrosis when last examined.

CONCLUSIONS

1. A procedure for construction of a new lateral spinal support by autogenous grafts has been recorded.

2. A circumduction fusion, when solid, has been shown to be effective in immobilizing the spine and arresting disease.

3. It is again emphasized that in patients with paraplegia due to tuberculosis of the spine, the treatment of choice is fusion across the involved area.

4. Wide laminectomy and facetectomy can produce a severely disabling condition and require lateral circumduction fusion to re-stabilize the spine.

5. Construction of a circumduction fusion may require numerous procedures to secure continuity.

6. Circumduction fusion can succeed, even when covering long areas of the spine, if repeated surgical procedures are accepted by the patient.

NOTE: We wish to acknowledge with thanks the help of our whole staff in the prolonged care and follow-up of these patients.

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The Effect of Anticoagulant Therapy on Bone Repair*

BY FRANK E. STINCHFIELD, M.D., BALU SANKARAN, M.B., F.R.C.S.C., AND ROBERT SAMILSON, M.D., NEW YORK, N. Y.

The stimulus for this study was the occurrence of pseudarthroses in four patients who had received anticoagulant therapy for thrombophlebitis immediately after an operation. A controlled investigation, in which experimental animals were used, was undertaken to determine the possibility of there being a causal relationship between anticoagulants and poor bone healing. The method of study and results were as follows:

METHOD

Sixteen rabbits (chinchilla type, three to five kilograms in weight) and ten mongrel dogs (ten to fifteen kilograms in weight) were used as experimental animals, and an equal number of animals were used as controls. This made a total of fifty-two animals. Each animal was anaesthetized with sodium nembutal (one cubic centimeter per 2.5 kilograms of body weight, each cubic centimeter containing sixty milligrams). The left iliac crest was exposed through a four-inch skin incision, the length of the incision being the same in both rabbits and dogs. The ilium was then exposed subperiosteally, and

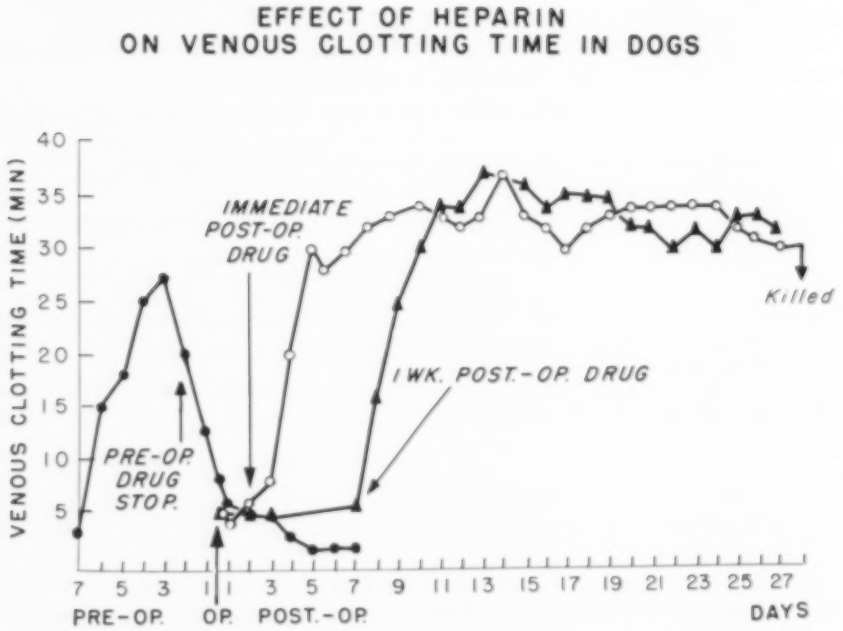

CHART I

The time in days is listed on the horizontal, and the venous clotting time in minutes is listed on the vertical. The solid dots represent animal No. A189, who received heparin preoperatively; the white dots represent animal No. A177, who received heparin immediately after the operation; and the black triangles represent animal No. A179, who received heparin one week after the operation.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 1, 1955.

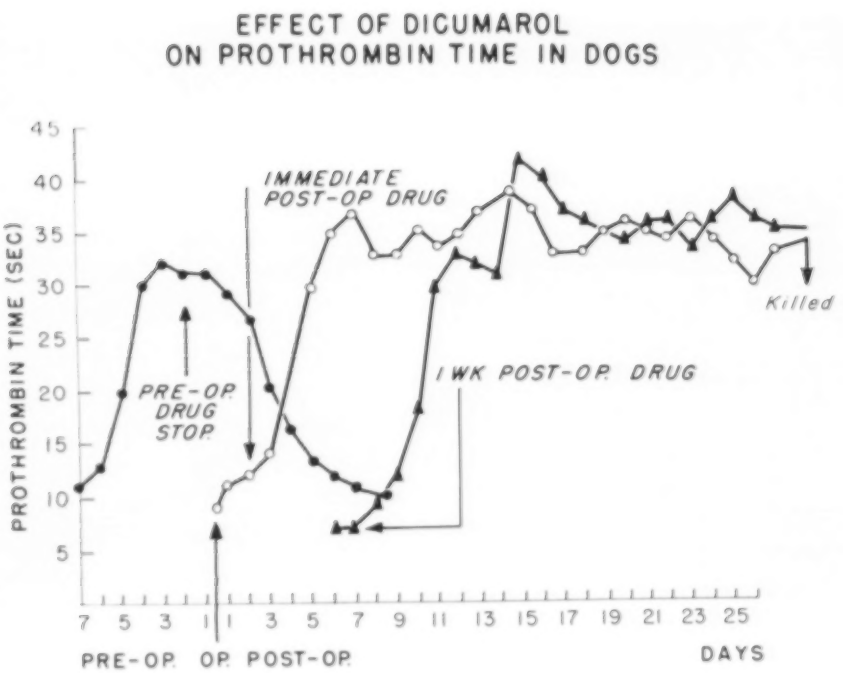

CHART II

The time in days is listed on the horizontal, and the prothrombin time in seconds is listed on the vertical. The solid dots represent animal No. A190, who received dicumarol before the operation; the white dots represent animal No. A181, who received dicumarol immediately after the operation; and the black triangles represent animal No. A185, who received dicumarol one week after the operation.

a semicircular disc of bone was removed with a Stryker saw. The disc, which was the same size for both rabbits and dogs, was divested of soft tissue and of any attached periosteum. It was then replaced into its bed, where it was held in anatomical position by two tantalum-wire sutures. The periosteum was not replaced. After the solidarity of the graft had been tested, the wound was closed in layers, black-silk sutures being used. All the wounds in both the experimental and control animals healed *per primam*.

DOSAGE

In the administration of heparin (Chart I *), the dosage established by Sandblom for rabbits was used for all animals. (About twenty-five milligrams per kilogram of body weight was given each day in two or three doses.) The dosage was controlled by maintaining the venous-clotting time at between twenty-five and thirty minutes. The Lee-White method was used to estimate the clotting time, and the estimations were made four hours after each administration of the drug.

In the administration of dicumarol (Chart II *), the dosage recommended by Taylor was used (about two milligrams per kilogram of body weight each day). The prothrombin time, as determined by the Quick two-stage method, was maintained at thirty to thirty-five seconds in both rabbits and dogs.

* The curves in Charts I and II are based on the findings in the dogs with the following tag numbers:

	Heparin	*Dicumarol*
Preoperative	Dog tag No. A189	Dog tag No. A190
Postoperative (twenty-four hours)	Dog tag No. A177	Dog tag No. A181
Postoperative (seven days)	Dog tag No. A179	Dog tag No. A185

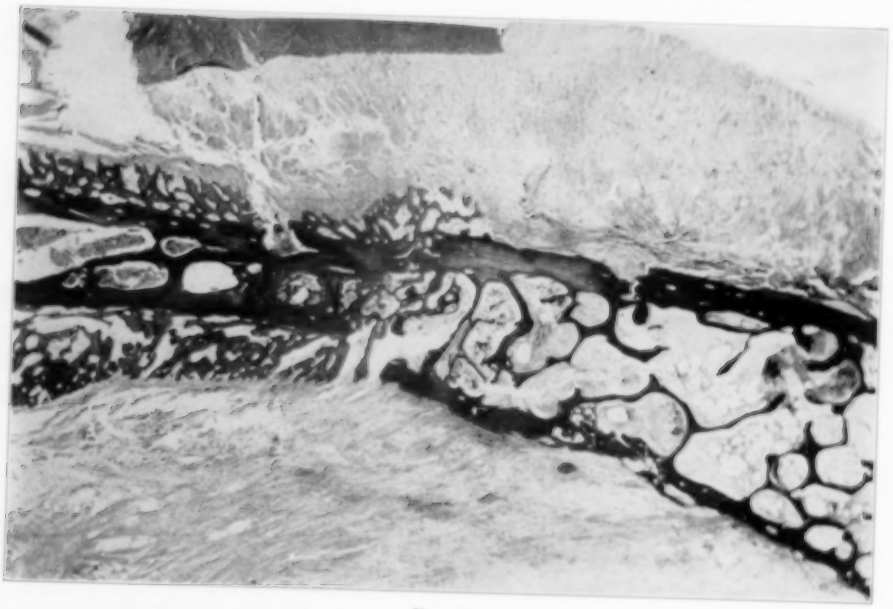

FIG. 1

Photomicrograph (× 41) of the graft site in a control dog showing normal bony union at the end of four weeks. Host bone on left, graft on right.

Anticoagulant therapy was given to the experimental animals in the following manner:

Group 1: Heparin was administered preoperatively to two rabbits and one dog. The drug was first given one week before the operation and was continued for four days. It was not given after the operation.

Group 2: Dicumarol was administered preoperatively to two rabbits and one dog. The exact procedure followed in Group 1 was used in this group.

Group 3: Heparin was given twenty-four hours after the operation to two rabbits and two dogs. It was continued for three weeks in the rabbits and for four weeks in the dogs.

Group 4: Dicumarol was administered to two rabbits and one dog in exactly the same way as heparin had been administered in Group 3.

Group 5: Heparin was given one week after the operation to two rabbits and one dog. It was continued for two weeks in the rabbits and for three weeks in the dog.

Group 6: Dicumarol was given one week after the operation to one rabbit and two dogs and was continued for the same lengths of time that heparin had been continued in Group 5.

Group 7: Heparin and dicumarol in combination were given to four rabbits and one dog. The drug therapy was begun twenty-four hours after the operation and was continued for three weeks in the rabbits and for four weeks in the dog.

Group 8: Heparin and dicumarol in combination were given to one rabbit and one dog seven days after the operation. They were continued for two weeks in the rabbit and for three weeks in the dog.

It is to be remembered that for each experimental animal used, a control animal was also used.

RESULTS

The rabbits, experimental and control, were sacrificed three weeks after the operation;

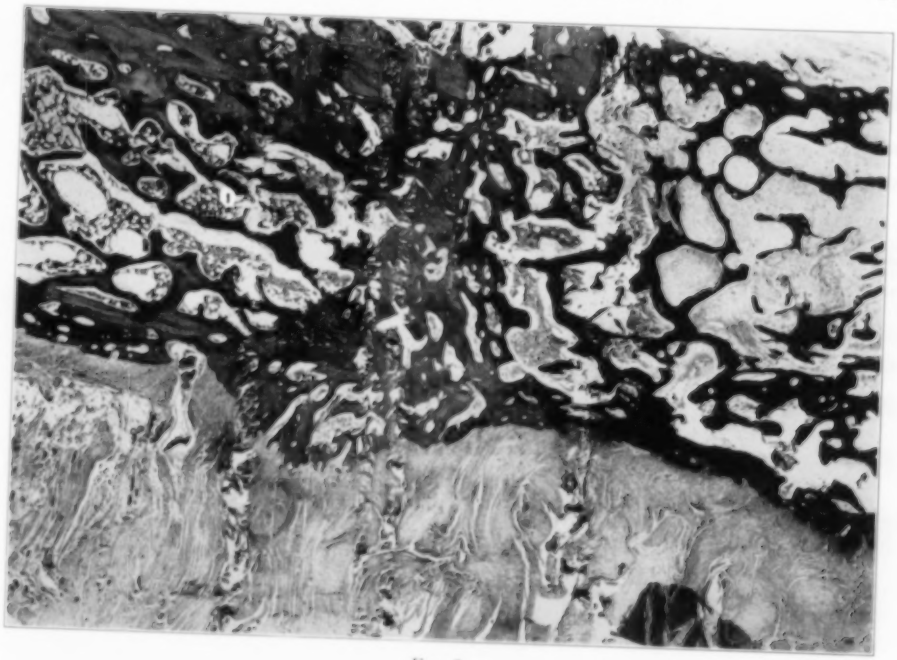

FIG. 2

Photomicrograph (× 41) of the graft site in a control dog showing normal bony union at the end of four weeks. Host bone on left, graft on right.

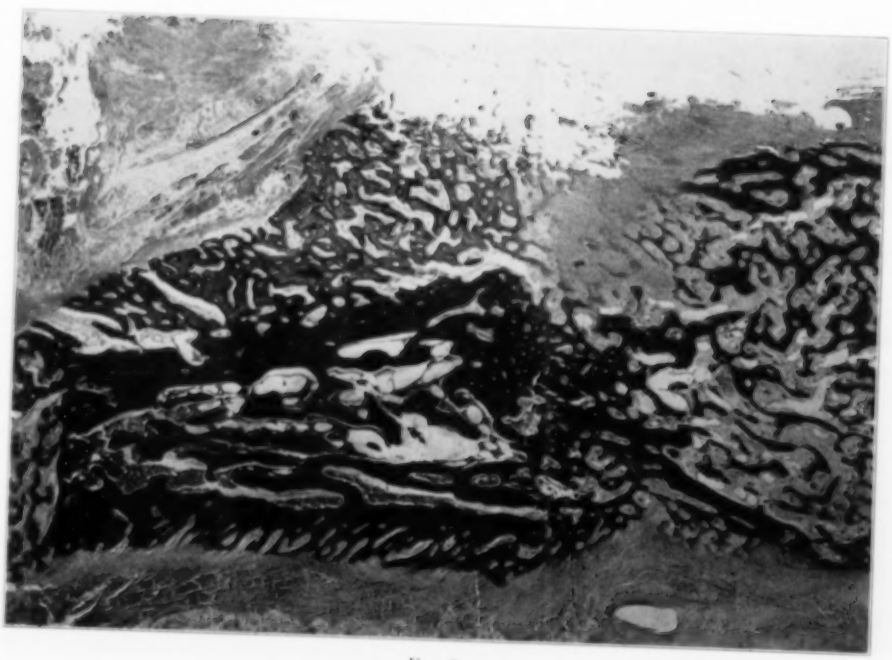

FIG. 3

Photomicrograph (× 41) of the graft site in an experimental dog to which heparin was give preoperatively. Host bone on left, graft on right.

and the dogs, experimental and control, were sacrificed four weeks after the operation. A complete autopsy was performed on each animal. During the experiment no animal lost any weight or showed any general untoward effect, and at autopsy no hemorrhage was

FIG. 4-A

Photomicrograph (× 41) of the graft site in an experimental animal to which dicumarol was given during the week before the operation. Host bone on left, graft on right.

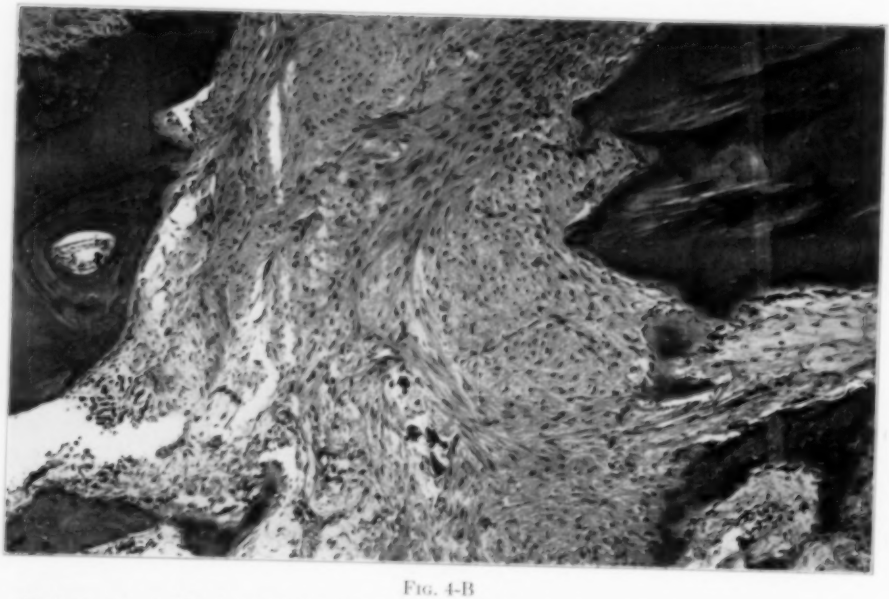

FIG. 4-B

High-power magnification (× 82) of the graft-host junction in the specimen shown in Figure 4-A.

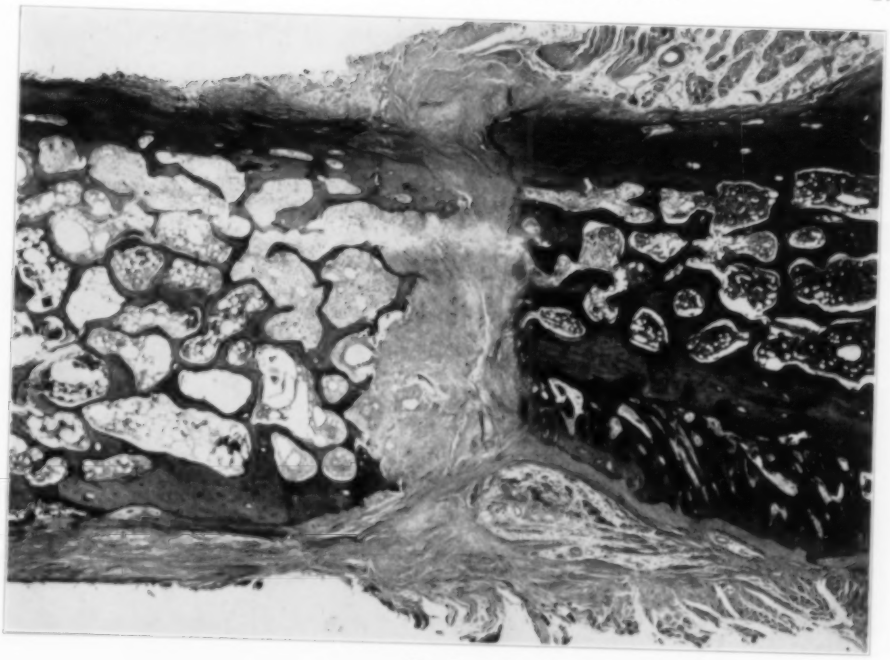

FIG. 5

Photomicrograph (× 41) of the graft site in an experimental animal to which heparin was given immediately after the operation. In this animal the drug was continued for four weeks. Host bone on left, graft on right.

noted macroscopically in any of the organs. As regards union of the graft to the host, the results in the rabbits paralleled those in the dogs but were less definite and striking.

Each photomicrograph shown is representative of the microscopic sections made for one of the groups of experimental animals. The microscopic sections were prepared by means of routine paraffin embedding in a technicon machine, and at least ten sections for each paraffin block were studied.

The results of the study were as follows:

A. Control Animals

In the control animals, bone bridged the graft site. This bone was immature, as is evidenced by the narrowed trabeculae and the great number of osteocytes per unit volume of bone which may be seen in Figure 1 (control dog, sacrificed four weeks after the operation). Progression toward union, as shown by continuity of the spongiosa between the graft and the host site, is apparent in Figure 2 (control dog). The findings in the rabbits, sacrificed three weeks after the operation, were similar to those in the dogs.

B. Animals Receiving Anticoagulant Therapy

Group 1: Heparin administered preoperatively. It was concluded that union was delayed in this group, for the degree of union obtained in these animals was less than that obtained in the control animals. Figure 3 shows a graft united to its host by very immature bone and fibrous connective tissue.

Group 2: Dicumarol administered preoperatively. The delay in union demonstrated in this group was the same as that found in Group 1. Figure 4-A shows a graft united to the host by both fibrous connective tissue and immature bone, the former occurring at the periphery of the graft site and the latter in the center. The amount of subperiosteal

FIG. 6

Photomicrograph (× 41) of the graft site in an experimental animal to which dicumarol was given immediately after the operation. The drug was continued for four weeks. Host bone on left, graft on right.

FIG. 7

Photomicrograph (× 41) of the graft site in an experimental animal to which dicumarol was given one week after the operation. The drug was continued for three weeks. Host bone on left, graft on right.

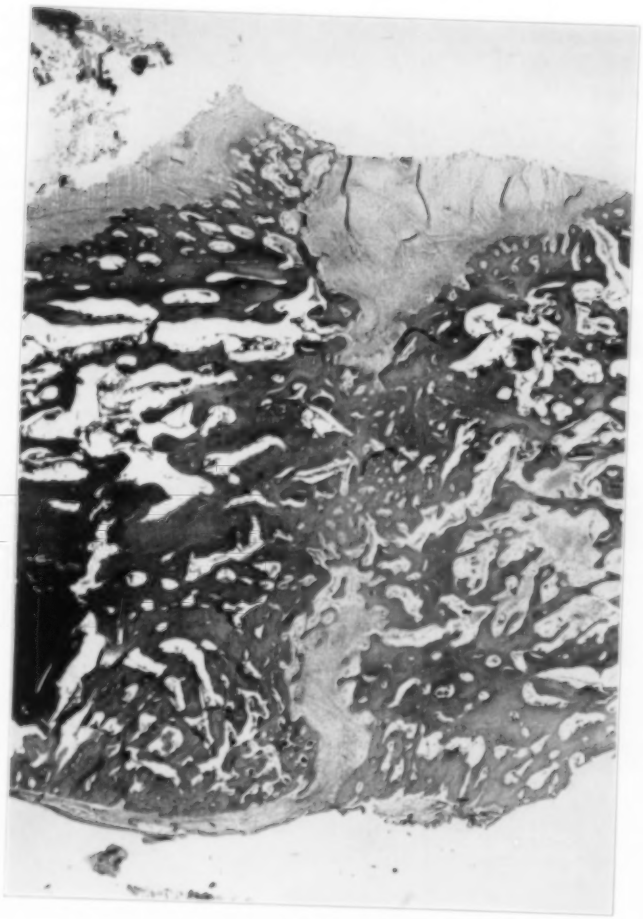

FIG. 8

Photomicrograph (× 41) of the graft site in an experimental animal to which dicumarol was given one week after the operation. The drug was continued for three weeks. Host bone on left, graft on right.

callus on the host side of the graft in this animal was much less than that in the control animals. Figure 4-B is a high-power magnification of the peripheral zone of fibrous union which appears in Figure 4-A.

Group 3: Heparin administered immediately after the operation. In the animals of this group union was even more delayed than it was in the animals of Groups 1 and 2. In Figure 5 fibrous tissue is apparent at the graft site, but there is no evidence of bony bridging. The amount of subperiosteal callus on the host side of the graft is less than that found in the animals of Groups 1 and 2. One of the experimental animals in this group, a dog, was sacrificed six weeks after the operation. The findings observed in this animal were similar to those found in the other animals of the group.

Group 4: Dicumarol administered immediately after the operation. The changes in the animals of this group were more marked than those in the animals to whom heparin was given immediately after the operation. Figure 6 shows a wide zone of fibrous connective tissue between the graft and the host, demonstrating that bridging of the graft site was more delayed in this animal than it was in the animals of Group 3.

Group 5: Heparin given one week after the operation. When given at this later date, the drug was much less effective than it was when given immediately after the operation. Figure 7, which is representative of the reactions seen in this group, shows that the graft site has been bridged with immature bone. The microscopic sections for this group were comparable to those for the groups in which the drugs were given preoperatively.

Group 6: Dicumarol given one week after the operation. The findings for this group were precisely the same as those for Group 5. Figure 8 shows the development of fibrous tissue at the periphery of the graft site, indicating that bony union had occurred in the central area.

Group 7: Heparin and dicumarol administered in combination immediately after the operation. More interference in bony union was demonstrated in this group than in any other group, a finding which has since been sustained by further experiments. (Since the original study was made, fifteen additional animals have been tested with heparin and dicumarol combined.) Figure 9, in which roentgenograms of an experimental and a control animal are compared, shows that in the former there was complete dissolution of

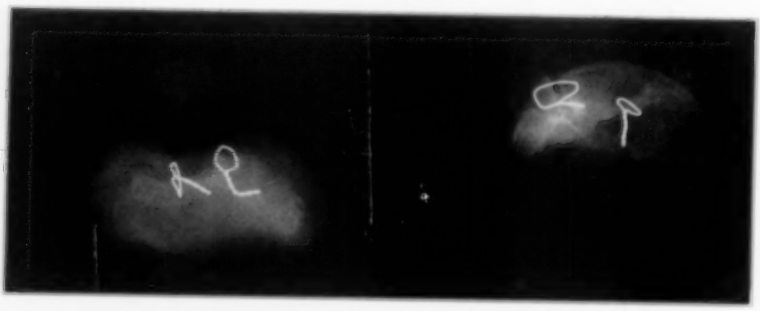

FIG. 9

Roentgenograms showing the ilium of a control animal (right) and the ilium of an experimental animal (left) to which heparin and dicumarol were given in combination immediately after the operation. The drugs were continued for four weeks.

the graft. Figure 10, a typical microscopic section, also shows pronounced changes. There is evidence in this section that no reparative bone formation had occurred and that the fibrous-tissue formation was less in this group than it was in any of the other groups.

Group 8: Heparin and dicumarol given in combination one week after the operation. The delay in union of the animals of this group was greater than the delay in union in any of the animals to which the drugs were given singly but was less than the delay in union in the animals to which the drugs were given together immediately after the operation. In Figure 11 the presence of abundant fibrous connective tissue in the interval between the graft and the host is shown, but there is no evidence of reparative bony bridging across the graft site.

DISCUSSION

To the authors' knowledge, this is the first series of experiments in which blood coagulation has been related to bone repair. Although, as it is generally recognized, heparin and dicumarol affect blood coagulation in entirely different manners, they have a parallel effect on bony healing, as has been shown by the microscopic sections made for this study. In their attempt to explain this experimental finding, the authors realized that certain working hypotheses had to be accepted. These hypotheses are as follows.

The adverse effect of anticoagulants on bone healing may be the mechanical result of a lack of fibrin clots. Clotting does not normally occur in the absence of ionized calcium,

FIG. 10

Photomicrograph (× 41) of the graft site in an experimental animal to which heparin and dicumarol were given in combination immediately after the operation. The drugs were continued for four weeks. Host bone on left, graft on right.

for calcium probably acts as a catalyst, possibly through its union with thromboplastin. The optimum amount of calcium required for clotting increases as the concentration of prothrombin decreases. Dicumarol may act as a factor in the diminution of the prothrombin concentration and thus may mitigate against there being a sufficiently high local calcium concentration for bony union to occur.

Chondroitin-sulphuric acid, a mucopolysaccharide, is felt to be essential for the formation of a calcifiable bone matrix [1]. It is suggested that heparin, another mucopolysaccharide closely resembling chondroitin-sulphuric acid, may act through a substrate competition mechanism [3] to replace or alter the normal matrix mucopolysaccharide and thus to prevent the formation of a calcifiable bone matrix.

The sections made from the control animals in this study illustrate the fact that bone healing originates some distance from the fracture or graft site and progresses toward the gap. The power to "induce" this reparative process is lacking in animals to which anticoagulants have been given.

Numerous microscopic sections were made for the group of animals to whom the drugs

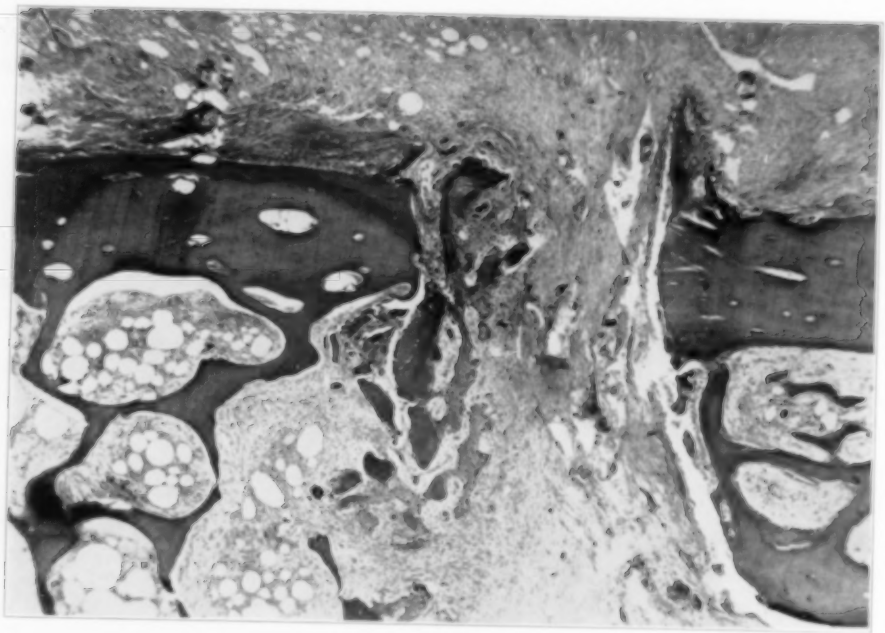

FIG. 11

Photomicrograph (× 41) of the graft site in an experimental animal to which heparin and dicumarol were given in combination one week after the operation. The drugs were continued for three weeks. Host bone on left, graft on right.

were given in combination immediately after the operation (Group 8). (For these sections toluidine-blue stain was used.) A comparison of these sections with sections made for the control animals shows that in the experimental animals there was a considerable decrease in the amount of mucopolysaccharide that was present at the graft site (Table I). Studies are now being made to determine the mucopolysaccharide content of the animals in the other experimental groups.

In the studies of the sections made from the animals in Group 8, it was shown that the decrease in the mucopolysaccharide content was not evenly distributed throughout the graft site. At the point of elevation of the periosteum on the host side of the graft, mucopolysaccharide activity was maintained to a minimal extent, whereas in the fibrous tissue at the site of non-union this activity was altogether lacking. The microscopic studies showed that this decrease in mucopolysaccharide concentration was almost directly comparable with and proportionate to a decrease in cellular activity.

There are two possible explanations for the findings of this study, one involving mechanical conditions and the other cellular conditions: (a) mechanical: there may be a lack of scaffolding in the form of the fibrin clot upon which the osteoblasts form bone; and (b) cellular: due to the toxic effect of the anticoagulants, there may be a definite diminution in the number of cells at the graft site or there may be an alteration in the normal metabolic process in the bone matrix.

SUMMARY

1. Twenty-six control and twenty-six experimental animals were studied.

2. In the control rabbits bony union occurred in four weeks; in the control dogs it occurred in six weeks.

3. When the animals received anticoagulants in the preoperative period, they showed evidence of delayed union.

TABLE I

HISTOLOGICAL STUDIES OF BONE UNION AFTER ADMINISTRATION OF HEPARIN AND DICUMAROL

Anticoagulants	Appearance of Graft	Periosteal Proliferation Host Side of Graft	Appearance of Central Host-Graft Junction	Mucopolysaccharide Content at Graft Site
Control animal	+ + + + appositional new bone	+ + + +	Mature bone	+ + + +
Heparin preoperatively	+ + + appositional new bone Fibrous marrow replacement	+ + +	Immature bone	Not done
Dicumarol preoperatively	+ + + appositional new bone Fibrous marrow replacement	+ + +	Immature bone	Not done
Heparin postoperatively (immediately)	+ + appositional new bone Fibrous marrow replacement	+ +	Minimal evidence of bony union	Not done
Dicumarol postoperatively (immediately)	+ + appositional new bone Fibrous marrow replacement	+ +	Minimal evidence of bony union	Not done
Heparin postoperatively (seven days)	+ + + appositional new bone Fibrous marrow replacement	+ + +	Immature bone	Not done
Dicumarol postoperatively (seven days)	+ + + appositional new bone Fibrous marrow replacement	+ + +	Immature bone	Not done
Heparin and dicumarol (in combination) postoperatively (immediately)	No appositional new bone Fibrous marrow replacement	+	No evidence of new bone	+
Heparin and dicumarol (in combination) postoperatively (seven days)	+ appositional new bone Fibrous marrow replacement	+ +	Minimal evidence of bony union	Not done

4. When the anticoagulants were given in the immediate postoperative period, fibrous union resulted.

5. When heparin or dicumarol were given one week after the operation, delayed union occurred.

6. It is not the authors' intention to conclude from this study that non-union will necessarily occur in a patient who has received anticoagulant therapy; they feel, however, that the possibility of its occurring must be considered.

7. The findings of this experimental study are of interest and may have a clinical significance and application. It is hoped that these findings will stimulate further interest in the general field of fibrous tissue behavior.

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DISCUSSION

Dr. Charles H. Herndon, Cleveland, Ohio: The authors are to be commended for recognizing the implication of the development of pseudarthroses in patients who had received anticoagulant therapy. Their evidence that the administration of dicumarol and heparin will seriously affect bone healing in rabbits and dogs is clear-cut and decisive. This finding is significant not only from a clinical standpoint but also because of its implications with respect to the general problem of bone healing.

The authors have not attempted to compile evidence as to why osteogenesis was retarded in the animals receiving anticoagulants; they have suggested certain theoretical possibilities, however. It should be noted that when the authors speak of giving anticoagulants immediately after the operation, they mean twenty-four hours after the operation. This is important. Normally one would expect clotting to occur at the bone-graft site within twenty-four hours. Furthermore, when autogenous bone grafts have been applied to the tibia and femur in dogs, we have found that an early internal osteofibrous callus usually forms within seven days following grafting and that in some cases partial fibrous union to the host also occurs. The fact that there is definite retardation of bone healing when the anticoagulant therapy is not started until one week after the operation would indicate that this retardation may be totally unrelated to the action of the blood-clotting mechanism. The effect of heparin may well be the result of its acting in competition with chondroitin sulphate, as the authors suggest; and it is possible that the effect of dicumarol may be due to the fact that it blocks the action of Vitamin K as a component in certain oxidizing reduction systems. Recent work indicates that Vitamin K is implicated in the breakdown of glycogen into glucose phosphates. It is conceivable that if this effect of Vitamin K is blocked by dicumarol, there would be a defect in the mechanism which makes available the phosphate ions necessary for bone formation. This hypothesis is pure theoretical speculation, but it warrants consideration.

It is probable that a continuation of these investigations will help to further explain the metabolic factors involved in bone formation. In the meantime, it is apparent from the material presented that we should be extremely cautious in administering heparin or dicumarol to patients in whom bone healing is occurring.

Dr. Arnold G. Ware, Los Angeles, California: Since anticoagulants are used extensively, serious consideration should be given to the observations of Dr. Stinchfield and his collaborators.

The specific mode of action by which heparin and dicumarol delay bone healing is of interest. The authors have indicated that each drug may effect bone healing in a different manner. It seems more probable, however, that the drugs act in the same manner, for they both inhibit fibrin formation either directly or indirectly, and it may be that fibrin formation is essential to bone healing not only during the first twenty-four hours, but also for some time thereafter. This possibility could be studied easily by depriving animals of fibrinogen through the use of agents such as streptokinase. Purified fibrinogen could be administered at any point during the healing process.

I hesitate to accept the hypothesis that dicumarol may cause a reduction in the calcium-ion concentration.

It is obvious that caution should be exercised in administering anticoagulants to patients in whom bone healing is occurring. To my knowledge, there is no evidence that the repair of other tissues is delayed by the use of anticoagulants.

Congenital Pseudarthrosis of the Tibia Treated by the Intramedullary Nail

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From the Department of Orthopaedic Surgery, The Royal Infirmary, Manchester

Reviewing the etiology of congenital pseudarthrosis of the tibia, McFarland came to the conclusion that mechanical factors were probably the most, and local defects of osteogenesis the least, important. The persistence of angular deformity is likely to expose a graft applied directly to a pseudarthrosis to such powerful and repeated angulatory strains, as a result of the "bow-string" action of the calf muscles, that any ordinary method of internal fixation is likely to be loosened.

Trueta is of the same opinion and, on the experience of an isolated case in 1947, suggested that the only adequate way of controlling these powerful angulatory strains would be by the use of a strong intramedullary nail. McFarland, accepting as insuperable the mechanical difficulties of immobilizing these tiny bones by means of onlay bone-grafts, has abandoned in his "by-pass" operation the classical principle of bone-grafting, that is, the immobilization of the pseudarthrosis by mechanical means combined with the application of the graft directly to the site of the non-union. In the by-pass operation the graft spans the site of the pseudarthrosis, but does not necessarily lie in contact with it. It is immobilized only in so far as it is exposed to longitudinal compression forces as a result of being "sprung" into position on the concave side of the pseudarthrosis. Angulatory strains are absent, and the graft is exposed only to longitudinal compression forces compatible with normal physiology.

The mechanical difficulty in performing a sound double-onlay graft as recommended by Boyd is particularly evident when the pseudarthrosis lies in the distal quarter of the tibia, because the purchase obtained on the distal fragment may be inadequate to resist angulatory strains. It is especially at this level that the mechanical superiority of the intramedullary nail reveals itself, *but only provided that* one accepts the drastic recommendation of transfixing the tarsus in order to perfect the purchase of the nail on the short distal fragment of the tibia. This method has the advantage over the by-pass graft that it restores some of the length lost in the angular deformity and gives a better cosmetic result. At the same time, it shares the physiological features of the by-pass graft in that the rigid nail denies any element of angulatory movement to the graft and exposes the pseudarthrosis site only to longitudinal compression forces.

Congenital pseudarthrosis of the tibia is notorious for its tendency to recur after what initially has apparently been a successful operation. Late deterioration of the graft is so common that McFarland warns against accepting any result as successful under a minimum period of three years. Boyd would seem to be even more cautious than this and, if the medullary canal has not been reconstituted, he stresses that the site of the graft is not completely safe until puberty is reached. At the time of writing, the postoperative periods of follow-up in the two cases to be reported are seven years in Case 1 and five and one-half years in Case 2.

CASE 1. V. M., a girl, was born on January 6, 1939. No abnormality was noticed at birth. The pseudarthrosis apparently started as a result of a fall in June 1941; she was taken to a hospital and a cast was applied. On November 7, 1941, she was taken to another hospital where the diagnosis of congenital pseudarthrosis was made and a cast was applied in an attempt to correct a severe deformity. A sliding tibial-bone graft was inserted June 30, 1943, and plaster fixation was continued. Non-union was still present in August 1944 when she was first admitted to the Manchester Royal Infirmary with five centimeters of shortening, marked bowing, and extreme mobility (Fig. 1-A). On February 19, 1945, a second bone-grafting operation

was performed; a massive graft from the opposite tibia was inserted into the medulla of the distal fragment and was screwed to the surface of the proximal fragment (Fig. 1-B). The screws were removed on November 11, 1946, when union appeared to be firm. Union appeared to be firm on examination on May 13, 1947. Mobility was present on July 3, 1947.

The child was operated upon for a third time on September 13, 1948, for the purpose of inserting intramedullary fixation. She had at that time 7.5 centimeters of true shortening and a very mobile fracture

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Anteroposterior and lateral roentgenograms made in August 1944.

Fig. 1-B: Anteroposterior and lateral roentgenograms made in February 1945 after a massive graft from the opposite tibia was inserted into the medulla of the distal fragment and screwed to the surface of the proximal fragment.

FIG. 1-C

FIG. 1-D

Fig. 1-C: Anteroposterior and lateral roentgenograms made in September 1948 before third operation.

Fig. 1-D: Anteroposterior and lateral roentgenograms made in June 1949, nine months after operation.

FIG. 1-E

FIG. 1-F

Fig. 1-E: Lateral and anteroposterior roentgenograms made in December 1953, four and one-half years after operation.

Fig. 1-F: Roentgenogram of both legs made in March 1954 after extraction of the intramedullary nail and resection of the left tibia.

(Fig. 1-C). It was found necessary first to lengthen the tendo achillis in order to overcome the bow-string action of the calf preventing correction of the 90-degree deformity. On exposing the fracture, the distal fragment appeared to have a normal blood-supply, whereas the proximal fragment was white and avascular and looked like a pointed ivory pencil without a medullary canal. An attempt to align the fragments was successful only after cutting further tight fascial structures in the calf. A Steinmann nail twenty centimeters long and four millimeters thick was then driven through the distal fragment and out through the sole of the foot. To drive the nail back into the proximal fragment it was necessary first to make a drill hole in order to search for the medullary canal. Once this was found the operation was completed easily. The nail was driven as high into the tibia as possible by using a punch through the wound in the sole of the foot. Osteoperiosteal slices cut from the opposite tibia were then packed around the operation site and the wound was closed.

Weight-bearing in a plaster cast was allowed in October 1948 and the cast was discarded after nine months when on roentgenographic investigation, consolidation appeared to be satisfactory (June 21, 1949) (Fig. 1-D). The condition four and one-half years later (December 8, 1953) is shown in Figures 1-E and 1-G.

On April 15, 1953, the discrepancy of 7.5 centimeters in leg length was reduced to 2.5 centimeters by resecting five centimeters from the opposite tibia. The intramedullary nail was extracted on March 17, 1954.

The present condition is shown in Figures 1-F and 1-H. There is 2.5 centimeters of shortening and there is fibrous ankylosis of the ankle. The ankle is symptomless and the patient leads a perfectly normal life at school.

CASE 2. M. S., a girl, was born November 17, 1942. At birth it was noticed that her right leg was deformed and that the foot was inverted. When three months old she attended an orthopaedic clinic and molding exercises were started and were continued once a week for one year. Between weekly moldings the leg was strapped to an external splint which was replaced each week. After a year the mother was told that a gap in the bone had been revealed by roentgenograms and a plaster splint was then applied. When she was one and one-half years old bone-grafting was performed by Prof. T. P. McMurray at the Liverpool Children's Hospital, but shortly after the operation it became evident that signs suggestive of a cerebral tumor were developing. She was transferred to the Manchester Royal Infirmary where Sir Geoffrey Jefferson successfully removed a glioma from the region of the optic nerve. It was at this point (September 1945) that she came

FIG. 1-G FIG. 1-H

Fig. 1-G: Photograph made in April 1953 showing discrepancy of 7.5 centimeters in leg length.

Fig. 1-H: Photograph made in March 1954 after leg-length discrepancy was reduced to 2.5 centimeters by resection of five centimeters from the left tibia.

FIG. 2-A

Fig. 2-A, Case 2: Anteroposterior and lateral roentgenograms made in September 1945 showing condition before operation.

under the writer's care, with a mobile pseudarthrosis of the tibia as shown in Figure 2-A.

On March 27, 1949, a second operation on the tibia was performed and a four-millimeter Steinmann nail, seventeen centimeters in length was inserted in order to procure intramedullary fixation. Thin osteoperiosteal slices of bone from the opposite tibia were applied to the surface of the pseudarthrosis. The leg was encased in plaster, and weight-bearing was permitted after four months (Fig. 2-B). Unfortunately, six months after the operation (September 17, 1949) the intramedullary nail spontaneously started to extrude through the sole of the foot and, therefore, had to be extracted (Fig. 2-C). The technical reason for this is discussed later. The roentgenographic evidence was that osseous union of the graft was present, although the cortex of the tibia was not completely reconstructed on the posterior aspect of the pseudarthrosis. A weight-relieving caliper splint was applied and the child was allowed to continue full activity. Despite the splint, she returned ten weeks later with evidence of spontaneous fracture, confirmed by roentgenograms (Fig. 2-D).

A four-millimeter Steinmann nail, twenty-one centimeters long, was therefore reinserted on March 30, 1950, and more osteoperiosteal slices were taken from the opposite tibia to cover the site of the refracture. A plaster cast was retained for six months, by which time roentgenograms indicated that consolidation was again present, this time more profusely than on the previous occasion (Fig. 2-E).

When the patient was examined on June 15, 1954, sound union was present with the nail still *in situ* (Fig. 2-F). The affected tibia was four centimeters shorter than its fellow. The clinical appearance of the child is seen in Figure 2-G.

The spontaneous extrusion of the nail in the second case, which necessitated further operation, was undoubtedly due to a misjudged attempt to "improve" the Steinmann nail as used in its original form in Case 1. The "improvement" took the form of sharpening both ends of the nail into very keen drill points to assist in the passage of the nail in two directions. This undoubtedly made the nail drift in the direction of least resistance under the influence of slight strains during weight-bearing. The lesson to be learned is that the distal end of the nail must be as blunt as possible, even at the expense of this making it difficult to drive the nail through the foot.

DISCUSSION

The tendency for late failure after what often appears to be a successful grafting operation in cases of congenital pseudarthrosis is very well recognized and is illustrated by the refracture in Case 2, which probably occurred about two months after the nail had been spontaneously extruded. At the time of this fracture (approximately eight months

FIG. 2-B

FIG. 2-C

Fig. 2-B: Anteroposterior and lateral roentgenograms made in July 1949, four months after insertion of intramedullary nail.

Fig. 2-C: Roentgenograms made in September 1949, six months after operation. The intramedullary nail started to extrude through the sole of the foot and had to be extracted.

FIG. 2-D

FIG. 2-E

Fig. 2-D: Anteroposterior and lateral roentgenograms made in November 1949, ten weeks after extraction of extruded intramedullary nail.

Fig. 2-E: Anteroposterior and lateral roentgenograms made in September 1950, six months after insertion of second intramedullary nail.

FIG. 2-F

Lateral roentgenogram of affected leg and anteroposterior roentgenogram of both legs made in June 1954. Sound union was present.

after operation) the roentgenogram showed what appeared to be quite good consolidation, yet it was apparently not able to resist the development of a fatigue fracture, even though protected in a caliper splint. The clinical details of this fracture were exactly those of a fatigue fracture, namely, that a limp developed, with minimal pain, without any known incident to account for it and without it being possible to decide precisely when the fracture started.

The tendency to late refracture, especially if sclerosis is present and if the medullary canal has not re-formed at the site of the old pseudarthrosis, has been stressed by Boyd. He recommends the wearing of a brace until the child is past puberty and the prophylactic use of additional bone grafts if follow-up roentgenograms suggest the threat of refracture.

The retention of a strong intramedullary nail for several years after grafting in congenital pseudarthrosis would seem to be a rational way of protecting the tibia from refracture, while at the same time allowing it to experience physiological compression in longitudinal direction in order to stimulate hypertrophy.

The technical details of how a long-term medullary splint can best be introduced and retained in the tibia have still to be perfected, but the experiences reported here suggest two interesting possibilities:

1. The useful fact that as the tibiae grew, the nail was in both cases retracted from its harmful position near the ankle joint. In Case 1, in the five years between Figure 1-D and Figure 1-E, the growth of the tibia caused an apparent spontaneous retraction of the

projecting lower end of the nail of 2.5 centimeters. In Case 2, in approximately four years during growth, the external projection of the lower end of the Steinmann nail was reduced by 2.5 centimeters so that the tip of the nail no longer interfered with the ankle joint (Fig. 2-F). In a child of about three years of age at the time of operation a retraction of about 2.5 centimeters can be expected in four or five years, and therefore presumably complete retraction in ten years.

2. The fortuitous placing of the nail achieved in Case 2 would, in the future, seem to be the method deliberately to be adopted so as to minimize damage to the ankle joint. If the nail is driven obliquely into the distal fragment in order to make it emerge from the front surface of the lower end of the tibia it can be made to pass through the neck of the talus and to emerge from the sole of the foot without actually traversing the ankle joint.

FIG. 2-G

Photograph made in June 1954. The affected tibia was four centimeters shorter than its fellow.

The use of a round Steinmann nail would not seem to offer any resistance to rotation, but as external support by plaster was used in both cases no trouble resulted from this factor.

An obvious criticism of the method is the damage to the ankle and tarsus which might be produced. The partial restriction of movement by fibrous ankylosis in both these patients has in fact caused no discomfort, nor has it limited activity. It must be remembered that this method is only likely to be indicated, or feasible, in children about two and one-half years of age or older and, at this age, these cases will almost certainly be the results of the failure of previous operations. Often in these cases the alternative to operation is amputation. The excellent cosmetic result in these two girl children is much preferable to a mobile ankle joint with tibial deformity. It is possible that with an improved technique suggested by these two experiences the nail may be kept from traversing the ankle joint as completely as it did in the first case. At the same time, it must be emphasized that the success of the method depends on securing complete fixation of the distal fragment and if this is as short as that in Case 1 the necessary fixation can only be obtained by transfixing the tarsus. In cases in which the pseudarthrosis is situated close to the lower end of the tibia the tendency for the distal fragment to be angulated backward by as much as 90 degrees is greater, and much more difficult to correct, than the less severe angulation present in pseudarthroses at a higher level. To correct a 90-degree angulation necessitates elongation of the calf, and even then soft tissues may still be under considerable tension. If the distal fragment is short and porotic the correction can only be held permanently, and the nail prevented from cutting out of the distal fragment, if the ankle and tarsus are deliberately transfixed. It seems likely that the intramedullary nail is especially indicated in pseudarthroses at this low level where the double-onlay graft as recommended by Boyd is difficult to fix to a short distal fragment. In any case permanent damage to the ankle and tarsus in a child will be less severe than would result from using this method in an adult, because the bone of the tarsus and the articular cartilage of the joints is still growing and replacing itself.

In both these cases there was no interference with the activity of growth in the distal

tibial epiphysis. This is indicated by the fact that retraction of the distal end of the nail took place in both cases — which must be attributed solely to growth at the distal epiphysis of the tibia.

No attempts were made to obtain leg-length equalization by epiphyseal arrest in the normal leg, the policy adopted being to shorten the opposite tibia in the later stages of childhood, if such a procedure by then is still indicated.

CONCLUSIONS

1. Two cases of congenital pseudarthrosis of the tibia treated by intramedullary nailing and the application of thin osteoperiosteal grafts, have both been successful as judged by the five-year results.

2. The essential feature of the method appears to be mechanical, in so far as all angulatory strains are converted into longitudinal compression forces. The grafts used were relatively unsubstantial and only adjuvant to the nail.

3. The intramedullary nail should remain *in situ* either permanently or for as many years as is necessary for the tibia to hypertrophy fully.

4. Three important details of technique are: (1) that the distal end of the nail should be blunt to prevent spontaneous extrusion through the sole of the foot, (2) that the nail should be passed through the anterior aspect of the lower end of the tibia so as to traverse the tarsus in the region of the neck of the talus and so avoid penetrating the ankle joint, and (3) that at the time of operation the distal end of the nail should reside in the tarsus, so making it impossible for it to cut out of the distal fragment of the tibia.

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Reconstructive Surgery of Hands with Injured Central Metacarpophalangeal Joints

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Following an injury to the center of the hand, the central digits may be anatomically intact distal to their metacarpophalangeal joints and yet still may be functionally worthless. This problem is of unusual interest, as it frequently affords an opportunity to use good tissue from one finger to rebuild another, the supposition being that two bad fingers can be used to build one good one. The decision as to which digit should be sacrificed involves several considerations, but the most important factor is the status of the metacarpophalangeal joint. Wounds in the center of the hand may be further complicated by damage to the motor branch of the ulnar nerve, and in addition to reconstruction of the damaged area, it may be necessary to plan for restoration of the power for pinch.

It is the purpose of this paper (1) to emphasize metacarpophalangeal-joint function as the key to the selection of an appropriate reconstructive operation and (2) to outline the possible reconstructive procedures that may be used in the treatment of both single and double joint injuries.

DESTRUCTION OF A SINGLE METACARPOPHALANGEAL JOINT

When a single metacarpophalangeal joint has been destroyed or ankylosed, the following procedures should be considered: (1) capsulotomy, (2) amputation with or without transfer of the adjacent metacarpal, (3) fusion, and (4) recession of the proximal phalanx into the palm.

1. *Capsulotomy*

Capsulotomy may be attempted when ankylosis is only moderately severe and when the capsule and collateral ligaments are the only structures involved. The dorsal extensor-tendon-splitting incision of Howard is generally accepted as the best approach for this procedure[8]. After the joint capsule has been opened, it is easy to determine whether or not capsulotomy will be successful. If the synovial membranes are adherent and inseparable, the joint can be opened like a book, but the proximal phalanx can never be made to rotate around the head of the metacarpal, as it does in normal joint motions. In a patient with this condition capsulotomy is futile. If the synovial membranes are not adherent and if the motor branch of the ulnar nerve and the intrinsic muscles are intact, the collateral ligaments should be excised. If the motor branch is not intact or if there is damage to the intrinsic muscles, however, only the ulnar collateral ligament should be excised and even this ligament should not be completely divided. After the intrinsic muscles have been destroyed, the collateral ligaments are the last remaining structure which provides lateral stability. Excision of these ligaments would result in a completely unstable joint which would promptly dislocate into severe ulnar deviation. This is a catastrophic complication for which nothing short of fusion of the joint can be done. Littler has emphasized this point, and the reader is referred to his article for illustrations and for further technical considerations with regard to capsulotomy[12].

Following capsulotomy the metacarpophalangeal joint must be kept in a position of flexion, a position which it will be impossible to maintain by means of plaster unless the wrist is placed in about 20 degrees of hyperextension. In order to avoid the use of plaster and to obviate immobilization of the wrist, the author has employed Kirschner-wire fixation (Fig. 1). A transverse wire is placed through the base of the metacarpals and

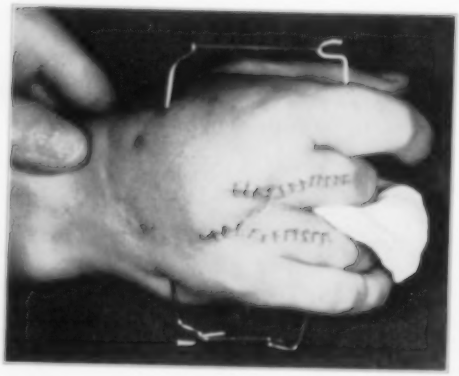

FIG. 1

FIG. 2-A

Fig. 1: The Kirschner-wire splint can be converted from an active into a dynamic splint by replacing the two lateral wires with rubber bands. (Reproduced by permission from E. E. Peacock, Jr.: Management of Conditions of the Hand Requiring Immobilization. Surg. Clin. North America, **33**: 1307, 1953.)

Fig. 2-A: A preoperative view. The index finger and its metacarpal have not yet been transferred to the base of the third metacarpal.

another transverse wire is drilled through the proximal phalanges of the involved fingers, care being exercised not to impale the intrinsic tendons as they pass over the dorsum of the fingers. During the period of primary healing, the two wires are connected by additional Kirschner wires. After primary healing has occurred, however, the latter wires may be replaced by rubber bands in order that the stationary splint may be converted into a dynamic splint.

2. *Metacarpal Transfer*

If amputation is to be done, one should consider the advisability of performing an osteotomy at the base of the adjacent outer metacarpal and of transferring this finger to the site of the amputated finger. This procedure will close the gap left by the amputation and will produce a symmetrical hand.

Although metacarpal transfer has been well reported in the past [7-9], it has failed to gain the general acceptance that its results warrant. Technically, it is not difficult to perform, and, when done correctly, it does not endanger the viability of the transferred finger (Figs. 2-A and 2-B). Furthermore, a carefully placed interdigital flap (Fig. 2-C) will prevent any scarring in the web space, where maximum elasticity is desired. An interdigital flap is developed from the side of the stump of the amputated finger, if a stump has been left, or from the floor of the cleft if the whole digit has been amputated. This flap is placed in a defect created in the side of the adjacent finger, and the scar is thus formed outside of the web. Kirschner-wire fixation in two planes will maintain perfect bone alignment in the transferred finger (Fig. 2-D).

Metacarpal transfer has been as successful for the fiifth finger as it has been for the index fingers. The cosmetic improvement obtained by this operation is obvious (Fig. 2-E). People notice stumps and empty spaces, but not normal fingers; and a hand which is symmetrical will go unnoticed by the casual observer. From a functional standpoint, the advantages of metacarpal transfer are twofold. The tendency of the surrounding fingers to deviate laterally is eliminated, and the cleft through which small objects escape is closed. The only disadvantage is that the hand's power of grasp is slightly diminished due to narrowing of the transverse metacarpal arch. This disadvantage may be of some significance to workers doing heavy labor but is of no consequence to people in occupations which do not require great strength.

FIG. 2-B

FIG. 2-C

Fig. 2-B: An operative view. The third metacarpal has been prepared, the index metacarpal has been mobilized, and a triangle of skin from the radial side of the ring finger has been sacrificed.

Fig. 2-C: Final operative view. A triangular flap of skin has been developed from the amputation site and has been sutured into a defect in the ring finger. By this procedure the suture line has been pulled out of the interdigital web.

FIG. 2-D

FIG. 2-E

Fig. 2-D: A postoperative roentgenogram showing the position of the Kirschner wires.

Fig. 2-E: A photograph showing the final result following metacarpal transfer of the index finger.

3. *Fusion*

Fusion of a metacarpophalangeal joint may be considered if the joint is painful and unstable but the distal portion of the finger is still useful. The case for fusion is strengthened when there are no other defects for which the tissue from the damaged finger could be more effectively utilized. It should be remembered, however, that fusion of a central metacarpophalangeal joint is not a sound procedure from a functional standpoint. When a central metacarpophalangeal joint is fixed, even in the functional position, its profundus

FIG. 3-A

FIG. 3-B

Fig. 3-A: A preoperative view showing severe destruction of the central metacarpophalangeal joints and of the surrounding soft tissues. Both fingers are functionally worthless.

Fig. 3-B: A preoperative roentgenogram showing severe destruction of the central metacarpophalangeal joints.

tendon is checked, which prevents the profundus tendons of all the other digits from moving through their natural range of motion. This condition makes attempts at full flexion painful. It has been suggested that in some respects a hand is better from a functional standpoint if all of the metacarpophalangeal joints are fused (in a functional position) rather than if only a single central joint is fused. Because of the possibility of functional disability, it has seemed advisable to follow the suggestion of Littler [13] and to fix the injured joint in the contemplated position with a Kirschner wire before the fusion is done. The patient may then test the mechanics of his hand as they will be after the fusion. If the performance of the hand is satisfactory, the fusion may be done. If there are more serious difficulties than there had been before, however, it is a simple matter to extract the wire under local anaesthesia.

It is important to be aware of the technical difficulties that are encountered in connection with a fusion procedure. Included among these difficulties are the following. (1) Knowing that it takes a relatively long time for fractures at the base of the proximal phalanx to heal, one might predict that it would take a similarly long time for fusion at this point to occur. Actually, four to five months may be required before the joint line is obliterated, and failure is so frequent that the implantation of key bone grafts is strongly recommended. (2) The joint cavity is so deep and narrow and the articular surface of the metacarpal head is so extensive that considerable bone and cartilage must be removed in order that the broad abuttment type of surface needed for a solid fusion may be provided. (3) After the ends of the bones have been prepared, it is difficult to bring them into apposition because of the redundant joint capsule and collateral ligaments. Apposition must be precise, however, and must be secured with as little damage to the overlying extensor mechanism as is possible. (4) The performance of extensive bone surgery beneath the gliding surface of a tendon provides ideal conditions for the tendon to become adherent to the bone. Such adhesion will interfere with the complete extension of the finger, for although it will not seriously affect the distal interphalangeal joint, it will limit the ex-

FIG. 3-C

FIG. 3-D

Fig. 3-C: An operative view. A local pedicle flap has been developed from the long finger, the ring finger has been amputated, and the scar has been resected.

Fig. 3-D: An operative view. A bone graft, fashioned from the proximal phalanx of the deleted finger, is being inserted. The purpose of this graft is to unite the third and fifth metacarpals with the fourth metacarpal.

FIG. 3-E

FIG. 3-F

Fig. 3-E: Postoperative roentgenogram. The bone graft has united to the third, fourth, and fifth metacarpals.

Fig. 3-F: Postoperative view. A local pedicle flap, taken from the long finger, has been used to reconstruct the damaged soft tissue.

tension of the middle interphalangeal joint. The incidence of adhesions may be reduced by careful handling of the tendon, by precise apposition of the joint surfaces, and by the insertion of an interposition paratenon graft.

The approach to fusion should be by means of a dorsal incision, with longitudinal splitting of the extensor tendon. After fusion has been performed, early motion in the

Fig. 3-G

Fig. 4-A

Fig. 3-G: Postoperative view of final result following transmetacarpal bone grafting.

Fig. 4-A: A preoperative view. The soft tissues of the hand have been damaged by a shotgun blast.

distal interphalangeal joint will be possible if internal Kirschner-wire fixation is used.

4. *Recession of a Digit*

The fourth alternative to be considered is recession of the finger into the palm. Again a finger with a functional distal end is an obvious prerequisite for the operation. An important advantage of this procedure is that it avoids both the limitation of flexion which is imposed by fusion and the narrowing of the transverse arch which follows metacarpal transfer; its main disadvantages are cosmetic. The object of the operation is to sacrifice the skin covering the proximal phalanx and to recess this phalanx into the palm as a metacarpal bone graft in order that the proximal interphalangeal joint will serve as a metacarpophalangeal joint.

Since this procedure will shorten the finger by the length of the proximal phalanx, the extensor and intrinsic tendons must also be shortened if effective power is to be restored immediately. An attempt should not be made to shorten the flexor tendons, however, and it is important to stay outside the flexor sheath, for bone surgery and flexor-tendon surgery performed at the same level usually result in loss of flexor activity. Actually, in this case, the flexors will shorten without any operative interference. The long extensor may be shortened by being split and woven into the lateral bands of the extensor mechanism.

Although odd in appearance, the hand that results from this operation is remarkably serviceable, and the procedure is useful where strength is of more importance than appearance. Kirshner-wire fixation in two planes should be used in order that early motion may be started.

Other Reconstructive Procedures

Arthroplasty is mentioned here only for completeness, for lateral instability, arthritis, and eventual ankylosis have ruined so many attempts at metacarpophalangeal-joint arthroplasty that the author is unable to recommend this procedure at this time. It is appropriate, however, to mention that several hand surgeons have described this operation and have felt that it was indicated in selected cases [3, 10, 14].

Use of artificial joints of Vitallium and steel has been uniformly disappointing. At

FIG. 4-B

FIG. 4-C

Fig. 4-B: A preoperative roentgenogram showing that the central metacarpophalangeal joints have been destroyed by the shotgun blast.

Fig. 4-C: Postoperative roentgenogram. The proximal interphalangeal joint has been placed in position between the metacarpal bridge and the ring finger. The joint was reversed in order that there might be an epiphysis in the metacarpal area.

some place and in some manner these metallic structures must be joined to bone [3], and where metal is joined to bone, there will sooner or later be resorption and instability. It is this factor of bone physiology which has seemed responsible for the long-range failure of artificial joints.

Transfer of toe joints has been performed successfully by Graham and Riordan, but the author has not had sufficient experience with this procedure to make any comment other than to refer to the publications of these men on the subject [4, 6].

INJURIES INVOLVING TWO METACARPOPHALANGEAL JOINTS

The problem is considerably more complex when an injury has been so extensive as to damage or destroy both of the central metacarpophalangeal joints. In such an injury the structures between the joints will also be damaged, with the result that sensation and intrinsic power will be lost on one side of each finger. The most important extra-articular structure that is likely to be damaged by such an injury is the motor branch of the ulnar nerve; damage to this nerve will leave a seriously weakened thumb and deviated index finger.

Occasionally both central fingers are damaged so badly that neither is worthy of reconstructive surgery. In this case both should be deleted in order that maximum use of the rest of the hand may be obtained. It is, of course, possible, if cosmetic desires outweigh the need for function, to save the fingers by fusing them in an acceptable position. Two anaesthetic, immovable processes in the center of the hand handicap the function of the extremity so badly, however, that a patient treated in this manner will usually request amputation at a later date.

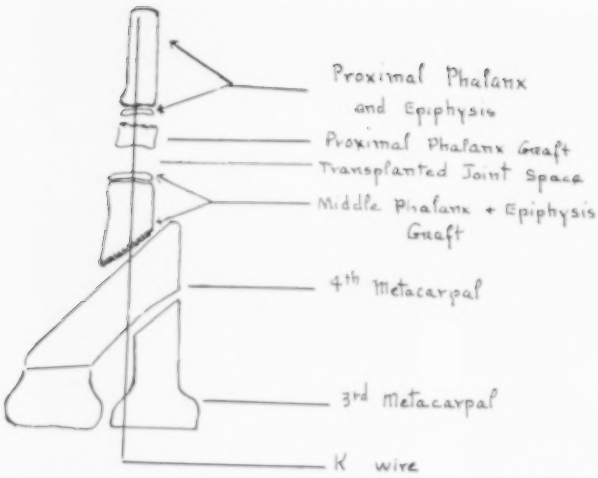

FIG. 4-D

Diagram of postoperative roentgenogram showing reversal of interphalangeal joint.

Normally there is about 20 degrees of motion in the fifth carpometacarpal joint. When the two center rays are absent, however, this motion is increased to such an extent that the fifth finger may drift into or away from the defect. This condition may be prevented by the use of a proximal phalanx from one of the fingers as a transverse metacarpal bone graft.

Both central fingers were amputated from the hand shown in Figures 3-A and 3-B. The proximal phalanx of the ring finger was used as a transverse bone graft to stabilize the fifth metacarpal, and the skin flap from one finger was utilized to resurface the dorsum of the hand (Figs. 3-C and 3-D). Figure 3-E shows the final roentgenographic appearance of this hand, and Figures 3-F and 3-G show the final photographic appearance. The fifth metacarpal was made completely stable by its fixation to the third and fourth metacarpals, and the patient obtained a remarkably strong grasp due to the presence of a solid, broad transverse metacarpal arch.

When two fingers are injured, one is usually more seriously damaged than the other, the more damaged finger frequently being the one with the most useless metacarpophalangeal joint. In this situation the finger with the greatest damage should be utilized as a source of parts for the reconstruction of the other finger. If the damage has been limited to the palm of the hand, it is possible to obtain from the finger to be sacrificed a joint, bone for grafting, material for a nerve transfer or graft, and skin for a local pedicle flap. The two flexors and the extensor motor unit which are proximal to the joint of the sacrificed finger may also be used.

It is evident that the most valuable structure which may be obtained from a finger

FIG. 4-E

FIG. 4-F

Fig. 4-E: The damaged soft tissues have been reconstructed by means of a local pedicle flap taken from the amputated third finger.

Fig. 4-F: A final view demonstrating that a position of full flexion can be attained by the transplanted joint.

FIG. 5-A

FIG. 5-B

Fig. 5-A: An operative view of fusion of the metacarpophalangeal joint in the thumb. The extensor tendons and radial nerves are being held back by rubber tape. The Kirschner wires cross in the phalanx of the thumb and then diverge as they pass over the joint space.

Fig. 5-B: A postoperative view. The pull of the long flexor on the distal phalanx is now transmitted through a stable arch to the first metacarpal.

is a joint. The distal interphalangeal joint is too small to be used as a servicable metacarpophalangeal joint, but the proximal interphalangeal joint has been used to excellent advantage. In fact, the obtaining of such a joint may alone justify the sacrifice of a badly damaged finger. An example of a free joint transplantation is shown in Figures 4-A through 4-F. In this case the proximal interphalangeal joint of the long finger was transferred to the site of the metacarpophalangeal joint of the ring finger, the joint being reversed in the hope that the epiphysis of the middle phalanx would provide growth in the metacarpal area. The epiphyseal cartilagenous plate in the phalanx of the reconstructed finger was not damaged.

The technique used in this transplantation was as follows. The fourth metacarpal was osteotomized and swung into the side of the third metacarpal in order that a stable base might be formed mid-way between the two marginal rays. The joint was then interposed between this base and the proximal phalanx of the ring finger, and stability was provided by the insertion of an intramedullary Kirschner wire. The third finger was deleted through a dorsal incision, and the volar skin flap was used as a local pedicle to the dorsum. In this hand the motor branch of the ulnar nerve had been spared so that no extra motor power was needed. Figures 4-E and 4-F show the final result two years later. The epiphysis is still visible, but past experience with transplanted epiphyses indicates that it is not likely to remain open for the normal length of time. In transplanted joints the articular surfaces generally undergo severe destruction, although there may still be growth of a pannus which gradually becomes organized into fibrocartilage.

One must be careful to leave adequate room for the pedicle between the center and outside fingers. If the pedicle is crowded when an attempt is made to place the new finger in a perfectly symmetrical position, the viability of the pedicle may be jeopardized because of inadequate venous return. It is a simple matter to excise the excess tissue from the flap several weeks later and to close any defect which is present between the fingers after a marginal blood supply has been secured in the flap.

A perforating injury will frequently destroy the common volar digital nerve of both fingers, which renders these fingers hemi-anaesthetic. If one of the fingers is to be sacrificed, the intact digital nerve of this finger should be cut at about the mid-way point in the proximal phalanx and should be transferred to the same point in the anaesthetic side of the other finger. In the performance of this procedure, it must be remembered that a digital nerve cannot simply be cut at its distal end and then withdrawn through a proximal incision, as can be done with tendons. A digital nerve has many tiny branches which must be carefully divided before the nerve is lifted from its bed. When these branches are to be

FIG. 6-A

FIG. 6-B

FIG. 6-C

Fig. 6-A: An operative view of a hand in which the adductor muscle and the soft tissue of the first web space have been destroyed. Previously an abdominal pedicle flap had been applied, but the thumb still hangs in a position of abduction. The sublimis of the ring finger has been withdrawn into the palm and will be pulled beneath the flexors by means of the clamp which appears in the palmar wound.

Fig. 6-B: The sublimis tendon has been split. Its two ends will be placed on either side of the proximal phalanx and sutured together so that the pull will come from both sides. Abduction as well as adduction will thus be made possible.

Fig. 6-C: A postoperative view showing the thumb in a position of adduction following transfer of the sublimis tendon.

cut, the trunk of the nerve must be exposed throughout its entire length and care must be taken that no tension is applied. If proximal traction pulls the nerve away from its branches, the axons within the sheath of the main trunk may be damaged. After such damage suture of the distal end of the nerve into the adjacent finger is not likely to be successful.

It takes a long time for the sensory cortex to adjust to a nerve transfer, and as long as two years after the above procedure, sensation is still interpreted as coming from the sacrificed finger. Most patients do not object to this condition, however, and it is not a serious drawback to the procedure. When the digital nerves have both been largely destroyed, segments of the digital nerve from the deleted finger are useful as free nerve grafts. Since at this level the nerves are purely sensory, the results of nerve grafting here are more favorable than they are elsewhere in the extremities.

The most serious functional disability which follows an injury to the motor branch of the ulnar nerve is weakness of pinch. This weakness is due to paralysis of the powerful adductor pollicis and of the first dorsal interosseous muscles. When these muscles have been paralyzed the metacarpophalangeal joint of the thumb cannot be stabilized and, of course, the power of adduction is nearly absent. Pinch is further reduced by the ulnar drift of the index finger.

Regardless of what is done in the center of the hand, the defects which result in weakness of pinch must be treated to some degree or the entire hand will be virtually worthless. The first procedure in this treatment should be fusion of the metacarpophalangeal joint of the thumb, as recommended by Littler [11]. This joint is relatively unimportant in the over-all function of the hand, and most people find that absence of motion here is hardly noticed. Once this joint has been fused, it is impossible for it to hyperextend during pinch (Froment's sign) and, furthermore, the forces exerted by the long tendons are

FIG. 7-A

FIG. 7-B

Fig. 7-A: A preoperative view showing deviation of the index finger following paralysis of the first dorsal interosseus muscle.

Fig. 7-B: An operative view. The short extensor of the thumb has been detached and has been withdrawn to the wrist where the tendon is exposed. The extensor will be reattached under the first dorsal interosseus where a clamp has been placed.

Fig. 7-C: A postoperative view following transfer of the extensor pollicis brevis to the first dorsal interosseus. Note that in a position for pinch the index finger is stable.

FIG. 7-C

transmitted to the thumb and its metacarpal as a single unit. Many times the improvement following this procedure is so marked that nothing further is needed, particularly if a strong pinch is not required.

The metacarpophalangeal joint of the thumb is easy to fuse. The procedure should be performed through a transverse dorsal incision, with lateral retraction of the extensor tendons and radial nerve. By this procedure the short extensor is, of course, made free for transfer elsewhere, if needed. After the joint has been opened, the articular surfaces are resected with an electric saw or osteotome. The resultant flexion angle between the phalanx and metacarpal should be 10 to 15 degrees, and the contact of these two bones must be firm and over a broad surface. Stability is provided by crossing Kirschner wires, as is shown in Figure 5-A. The wires are trimmed so that their ends are beneath the skin, and they are later removed under local anaesthesia. As a result of this operation a partially flail thumb becomes a stable arch, and the long flexor acts on the entire thumb, moving it as a unit and thus providing a substitute power for adduction (Fig. 5-B).

If more power is desired, tendon transfers must be performed, and for this purpose, the following different tendons may be used. (1) The sublimis of a sacrificed third or fourth finger is perhaps ideal for transplantation because of its length, power, and independent function. If this tendon is used, it should be withdrawn into the palm and should then be rethreaded beneath the flexor tendons so that it follows the paralyzed adductor muscle as far as the insertion of this muscle at the base of the proximal phalanx (Figs. 6-A through 6-C). It may be sutured into bone with a pull-out wire or into the adductor tendon with a buried silk suture. (2) When there is marked ulnar deviation of the index finger, pinch may be further strengthened by redirection of a flexor or extensor tendon to the lateral bands and intrinsic tendons of the radial side of the index finger. This procedure has been documented by Graham and Riordan [5]. (3) Another possible

procedure is transfer of the short thumb extensor to a paralyzed first dorsal interosseous muscle (Figs. 7-A through 7-C). The short thumb extensor is frequently an inconstant tendon, however, and may not be strong enough to be used, even when present. (4) If the flexors have been used as an adductor transfer, the indicis proprius or another extensor can be used as first dorsal interosseous transfer, as is recommended by Bruner.

CONCLUSIONS

1. The early treatment of injuries in the center of the hand should be directed toward the preservation of motion in the metacarpophalangeal joints.

2. Repair of the tendons and nerves and occasionally even of the bone should be delayed until the wounds in the damaged joints have healed and until motion has been restored.

3. Amputation should never be performed until it is certain that no further use may be made of the good parts of the finger which is to be deleted.

4. Single joint injuries can be treated by capsulotomy, fusion, or amputation combined with metacarpal transfer or recession of the digit into the palm.

5. A hand with a double joint injury may sometimes be reconstructed by combining the good parts of two worthless fingers into a single useful digit.

6. Multiple tendon transfers and joint arthrodesis may be performed to restore effective pinch to a hand in which the motor branch of the ulnar nerve has been disrupted.

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Paralytic Supination Contracture of the Forearm

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Twenty patients with paralytic supination contracture of the forearm were seen from 1942 to 1952; sixteen of them had had Erb's palsy, one had had an injury after birth to the brachial plexus, and in two the contracture had developed following infantile paralysis. There was bilateral involvement in two patients, in an eight-year-old girl with Erb's palsy and in a young man with transverse myelitis of the cervical segment of the spinal cord.

This contracture follows the selective weakness or paralysis of the four muscles arising from the medial epicondyle of the humerus, the pronator radii teres, the flexor carpi ulnaris, the palmaris longus, and the flexor carpi radialis. The latter three muscles are also volar flexors of the wrist. The supinatory muscles of the forearm, especially the biceps brachii, remain strong. In this series the supination deformity was fixed in all cases except in five patients with Erb's palsy. Yet, often, the supinated forearm could be rotated passively almost to the neutral position, but release would give rise to a rebound to the position of deformity, the "supination rebound".

A sequence of events follows the contracture in which the supination deformity plays the dominant role. The wrist dorsiflexes because the volar flexors of the wrist are weak or absent, while the dorsiflexors which have a secondary supinatory action are strong. There is also a gravitational drop of the wrist into dorsiflexion by reason of the supination position of the forearm. The wrist is often adducted by the pull of the extensor carpi ulnaris when its power is greater than that of the radial extensors of the wrist.

In the normal forearm, the head of the ulna in supination is in the volar position in relation to the radius, and dorsal to it in pronation. In this contracture, the small and sometimes misshapen head of the ulna is more or less fixed in this volar position so that its normal dorsovolar change in relative position is diminished.

Associated with this deformity, there is often a great weakness or paralysis of the hand, especially of the small muscles of the hand and of the flexors of the fingers. The paralysis of the hand is not the result of the paralysis of the forearm muscles; however, the position assumed by the fingers does depend on the position of the wrist and of the forearm. Usually, the fingers are flexed at the interphalangeal joints and extended to 180 degrees at the metacarpophalangeal joints in association with supination of the forearm and dorsiflexion of the wrist. The thumb is often drawn into the palm. This position of the digits results from the supination contracture. The distal phalanx of the thumb may be held in flexion, if the extensor pollicis longus is weak and the flexor pollicis longus is strong. In no case were the fingers clawed, since this deformity is the result of a volar flexion of the wrist.

A flexion contracture of the elbow is the almost inevitable companion of the supination contracture of the forearm, for the biceps is strong and the triceps is often weak. The important supinator of the forearm, the biceps brachii, works best in right-angled flexion of the elbow, and in this deformity the elbow is often held in this position.

The supination contracture is unsightly and awkward. There is a natural tendency for the patient to attempt to conceal it by abducting and medially rotating the shoulder. The medial rotation and abduction of the shoulder give the appearance of pronation to the forearm even though the forearm is supinated. When the elbow is flexed and the shoulder medially rotated, the shoulder must abduct, in order to bring the hand to the side. Conversely, when there is an undiscovered palsy of the medial forearm muscles, a

supination deformity of the forearm may become apparent when the medial-rotation deformity of the shoulder is first corrected by a plaster or brace which holds the limb in the so-called airplane position.

An active effort may be made to pronate the forearm by rotating the hand at the wrist joint. The normal wrist does not allow any significant passive turning of the hand at the wrist, for it is bound firmly by its strong ligaments and muscles. The loose-jointed wrist with lax ligamentous structure allows a passive dorsovolar movement of the hand at the wrist and even some passive rotation which is actually a twist. The wrist sometimes becomes hypermobile in the supination contracture of the forearm. In the girl with bilateral supination contracture of the forearm, the apparent pronation of the right forearm was the result of a 90-degree rotation of the hand at the wrist.

The constant presence of other deformities with the supination contracture of the forearm suggests that this contracture is really the primary link in a chain of deformities.

OPERATIVE SOLUTION

The deformity is ugly and operation is indicated, even if its only result is that the arm hangs naturally at the side of the body. The operation may restore some function to a useless or poorly used extremity. In bilateral supination contracture of the forearm, operation on at least one of the upper extremities would seem mandatory.

The shoulder component of the deformity should be corrected first. The restoration of the shoulder to the neutral position then reveals the true magnitude of the supination deformity. The supination deformity is corrected next, and this is followed by fusion of the wrist. Reconstructive surgery of the hand is the final step. The tendency is to fuse the wrist as the first operative procedure. In fact, the wrist had been fused in eight of these patients before they were seen for treatment of the supination deformity. Both wrists had been fused in the patient with transverse myelitis, the supination contracture having been left untreated. Four of the group with previous fusion of the wrist later needed osteotomy of the radius, and in two the wrist fusion had to be revised.

Although the flopping of the wrist into dorsiflexion during supination seems to make the palm an insecure carrying surface, Hendry believed that in patients who have a flail hand the position of full supination of the forearm was better than the mid-position, for it allowed the palm to carry objects. In a completely flail hand, he recommended strut stabilization of the thumb and tenodesis of the flexor and extensor tendons to the radius with the wrist held in slight dorsiflexion and the finger tips just in contact with the palm. Upon pronation, the wrist falls into flexion, thus tensing the extensors and causing the fingers to open. With supination, the reverse occurs; the weight of the hand and that of any object placed in it causes the wrist to extend and the fingers to close, giving grasp.

In the first of the two cases reported by Hendry, a man, thirty-two years old, had a complete paralysis of the left brachial plexus of three and one-half years' duration after a motorcycle accident. In the first operation, the forearm was turned into full supination by osteotomy of the radius after strut stabilization of the thumb and fusion of its metacarpophalangeal joint. Later, a posterior bone block of the elbow and fusion of the shoulder were done. The man became a conductor and was able to use the paralyzed limb to hold his ticket rack.

Supracondylar Osteotomy of the Humerus

This osteotomy aims to give simultaneous correction of the flexion contracture of the elbow and of the supination contracture of the forearm. It is a poor operation, for it creates an angular or bayonet deformity at the site of osteotomy. The turning of the forearm into pronation takes place at the site of osteotomy. The olecranon is displaced with the distal fragment of the humerus, so that it projects not posteriorly but laterally after the osteotomy. The correction of the supination contracture may be more apparent than real.

FIG. 1-A

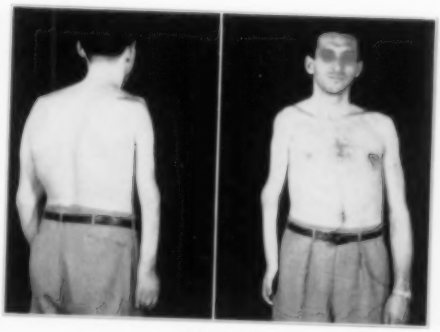

FIG. 1-B

Fig. 1-A: Preoperative photograph, April 6, 1942. All of the elements of the chain of deformities following supination contracture of the forearm were present.

Fig. 1-B: Postoperative photograph, November 1942. The correction of the flexion contracture of the elbow by supracondylar osteotomy of the humerus is shown. A bayonet deformity of the bone resulted. The lateral projection of the olecranon resulted from the medial rotation of the distal portion of the humerus carried out in order to achieve the apparent correction of the supination contracture of the forearm.

CASE 1. A man, twenty-four years old at the time he was admitted on April 2, 1942, had undergone several operations to correct the deformities of his right shoulder and wrist which followed the muscle imbalance of Erb's palsy (Fig. 1-A). The shoulder was held in 20 degrees of abduction, 20 degrees of flexion, and 90 degrees of medial rotation. The middle and posterior portions of the deltoid muscle were paralyzed, but the anterior fibers had some power. The patient could lift the arm in the sagittal plane to 90 degrees but could not abduct in the frontal plane. The trapezius was strong. The head of the humerus was subluxated posteriorly. The range of elbow motion was from 90 degrees of flexion to 155 degrees of extension. Full passive flexion of the elbow was blocked by the contact of the hand and forearm with the body. The biceps was strong and the triceps weak. The wrist was held in dorsiflexion of 25 degrees; the patient could extend it actively slightly more by the power of a transplanted tendon. The wrist could be brought into the neutral position by passive flexion. Finger power was very weak; the patient could extend only the index finger. The palm was flat with the thumb at the side of the hand. He could neither oppose nor abduct his thumb which was fixed in an adduction contracture.

A cone osteotomy through the surgical neck of the humerus corrected the triple deformity of flexion, abduction, and medial rotation of the shoulder on April 6, 1942. The arm was brought to the side of the body where it was held by a plaster-of-Paris spica. On June 1, 1942, a supracondylar osteotomy of the humerus overcame the flexion contracture of the elbow. The medial rotation of the distal humeral fragment pronated the forearm indirectly by tilting the elbow joint into a valgus position. On August 22, 1942, revision of the fusion of the wrist joint, capsulotomy of the carpometacarpal joint of the thumb, and section of the adductor muscles of the thumb were carried out (Fig. 1-B). Recurrence of the apparently corrected supination contracture of the forearm had taken place by March 1943. By means of osteotomy of the radius on March 15, 1943, the forearm was placed in pronation. At the same time, the base of the first metacarpal bone was osteotomized and the thumb was placed in a position of opposition. A Bunnell opponens transplant was then carried out.

The position of the extremity was good on April 13, 1943. The patient could oppose his thumb to the ring finger. He has not been seen again.

Torsional Osteoclasis or Osteotomy of the Radius

The supination deformity may be corrected by osteoclasis of the radius and ulna as done by Blount, who recognized this deformity, or it may be corrected by a cone or a greenstick osteotomy of the radius. This is the natural operative approach when manipulation of the forearm into pronation has failed to correct the condition. The forearm bones of young children can be broken over a wedge or in a well-padded, small Grattan osteoclast. The bones of older children and of adults are cut by open section. The forearm is immobilized in full pronation for six or more weeks until healing takes place. In one case, the forearm was manipulated into pronation. Six patients with Erb's palsy underwent osteotomy of the radius; two required re-operation later. In two patients, both bones of the forearm were manually broken before subsequent open operation, which in one case was an

FIG. 2-A

FIG. 2-B

Fig. 2-A: Preoperative photographs, August 1942, showed supination contracture of the forearm, flexion contracture of the elbow, and dorsiflexion of the wrist. Note the flexion deformity of the distal phalanx of the thumb. The shoulder was in the neutral position.

Fig. 2-B: Postoperative photograph, April 14, 1949, showing the forearm in partial pronation.

osteotomy of the radius and in the other, an osteotomy of the ulna; in both the supination deformity had recurred after osteoclasis. Osteotomy of the radius was done in the patient with the postnatal injury to the brachial plexus and in one of the patients with infantile paralysis. In one case, the ulna was osteotomized at a second operation to correct its disfiguring medial bowing. It was not necessary to release the distal radio-ulnar syndesmosis in any case.

Osteotomy of the radius changes the unsightly supination contracture into the more desirable pronation contracture. The postoperative effect of treatment of the supinated radius by osteotomy of the radius is that of a torque or twist of the bone, for the distal fragment of the radius is brought into pronation while the proximal fragment remains supinated. The twist occurs at the osteotomy site, mid-way between the distal and proximal ends. It is permanent unless the pull of the supinator muscles untwists the distal fragment of the radius while the callus at the site of osteotomy is still plastic. Recurrence frequently takes place and the operation may have to be repeated. Observation of these patients over a period of many years shows that the forearm has little active rotation after operation. Passive supination to the neutral position or just short of it is all that is possible.

CASE 2. A girl, eight and one-half years old in August 1942, had Erb's palsy of the right arm, the significant feature of which was the supination contracture of the forearm (Fig. 2-A).

The radius and the ulna were broken over a wedge on August 24, 1942, and the forearm was immobilized in pronation of 75 degrees. The forearm was held in the mid-position on July 2, 1943, as a result of partial loss of the correction. On attempted supination, the wrist dorsiflexed. The forearm could be passively pronated to 80 degrees and supinated to 90 degrees. On November 12, 1945, the recurrent supination contracture was corrected by osteotomy of the radius. At the same time, the tendon of the extensor carpi ulnaris was passed through the sheath of the extensor pollicis longus and the two tendons were sutured side by side at the level of the wrist.

On April 14, 1949, the arm was held naturally at the side of the body (Fig. 2-B). The patient was last examined on October 6, 1952, when she was nineteen years old. At that time, she could set her hair, as well as wash and wring out her clothes, but she could not write or use a knife and fork with this hand. The lower part of the forearm crossed the right hip. The elbow could be extended to 160 degrees. The forearm was maintained in the mid-position. Passive supination was possible to 90 degrees and passive pronation to 95 degrees. When attempting active supination, her wrist went into hyperextension, but ordinarily it was held in slight adduction and dorsiflexion. The thumb lay at the side of the index finger in the plane of the hand. She could abduct and extend the thumb actively, including its tip.

CASE 3. A woman, twenty years of age, with Erb's palsy was first seen in 1945 (Fig. 3-A). In 1928, the right shoulder had been stretched into abduction and external rotation and held in that position by a plaster-

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Preoperative photograph, February 23, 1945, showing the supination contracture of the right forearm and the thumb drawn into the palm. (Reproduced by permission from the *New York State J. Med.*, **48:** 390, 1948.)

Fig. 3-B: Postoperative photograph, October 4, 1945. The forearm was pronated and the radius was angulated dorsally and ulnarward. This was the appearance of the forearm in December 1950. (Reproduced by permission from the *New York State J. Med.*, **48:** 390, 1948.)

Fig. 3-C: Photograph, September 9, 1946, showing the result of the tendon transplantation stabilizing the carpometacarpal joint of the thumb so that the thenar muscles worked on a firm base. There was some active abduction of the thumb. (Reproduced by permission from the *New York State J. Med.*, **48:** 391, 1948.)

of-Paris spica. The supination contracture of the forearm was recognized in 1940. In 1942, another surgeon had arthrodesed the wrist to correct its ulnar deviation and had transplanted the flexor carpi ulnaris to the common extensor tendons of the fingers.

On March 26, 1945, the following procedures were carried out. The elbow was stretched into greater extension and the metacarpophalangeal joints of the fingers were flexed to correct their contracture in extension. The mid-part of the radius was sectioned and the forearm was rotated into pronation. The tendon of the extensor carpi ulnaris was transplanted through the sheath of the abductor pollicis longus to give abduction

FIG. 3-D

Roentgenograms made December 18, 1950. The shaft of the radius was angulated ulnarward and dorsally. After torsional osteotomy, the proximal portion of the radius was supinated and the distal portion pronated.

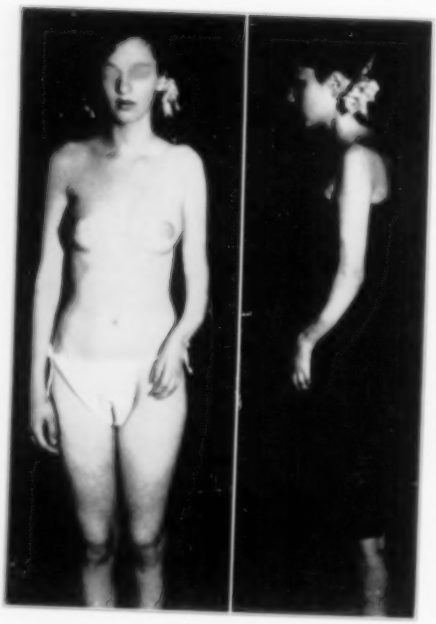

Fig. 4-A: Photograph, August 8, 1944, before revision of the osteotomy of the radius. Note the sharp dorsal and ulnar angulation of the radius and the corresponding deformity of the ulna which had not been osteotomized previously. Both bones were divided and the forearm was straightened and pronated.

to the indrawn thumb. The appearance of the forearm was improved (Fig. 3-B) and the tendon transplantation gave improved function to the hand (Fig. 3-C).

By December 18, 1950, the patient stated that she "could do almost anything" with the right hand. The forearm was pronated and the shaft of the radius was angulated ulnarward and dorsally. The ulna was bowed slightly, and its small head was displaced volarward (Fig. 3-D). The elbow could be actively extended to 170 degrees. The wrist was in the neutral position and could be flexed 10 degrees by intercarpal joint motion. The thumb was out of the palm, and the patient could grip objects.

Case 4. A fifteen-year-old girl with Erb's palsy of the left limb was first seen in 1944. Her wrist had been fused on July 28, 1937. In March 1944, the forearm was in full supination contracture and no passive pronation was possible. The ulna was bowed medially. The elbow could be extended to 110 degrees and flexed fully. There was some flexion of the fingers.

A cone osteotomy of the radius was performed on March 6, 1944, and a supracondylar osteotomy of the humerus to correct the flexion contracture was done on March 20, 1944. The supination deformity of the forearm recurred; medial bowing of the ulna and angulation of the radius at the osteotomy site had occurred. Accordingly, both the radius and the ulna were

Fig. 4-A

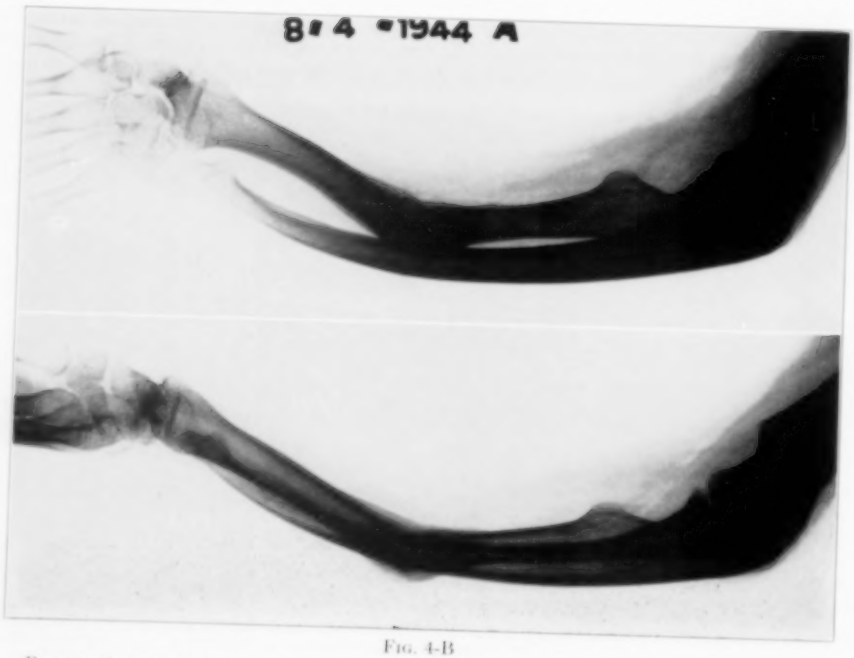

Fig. 4-B

Preoperative roentgenograms, August 4, 1944, showing the radius, which is longer than the ulna, to be angulated dorsally and medially. The ulna was bowed medially. Its head was small and displaced volarly. The wrist was fused but there was intercarpal motion.

Fig. 4-C: Photograph, March 21, 1946, before the removal of a sequestrum resulting from the tibial graft used in the fusion of the wrist. The forearm was in the same position when examined in March 1951.

sectioned on August 8, 1944. A fibrous union of the radius was found at this procedure (Figs. 4-A and 4-B). Following operation, union of both bones took place and the plaster-of-Paris cast was removed on October 10, 1944. The wrist fusion was revised, and transplantation of the extensor carpi ulnaris tendon through the sheath of the abductor pollicis longus tendon was performed to give abduction of the thumb in July 1945. A sequestrum, derived from the cortical tibial graft used in the Albee type of fusion, was removed on March 25, 1946 (Fig. 4-C).

In 1949, the forearm hung naturally at the side of the body in full pronation. Passive supination of the forearm was possible from 0 degrees to 75 degrees. The small misshapen head of the ulna was still volarly displaced (Fig. 4-D). Slight passive dorso-volar motion provoked a rough bony grating as the radius rubbed against the ulnar head. The wrist was solidly fused. The grip was fair and the transplant had a little power. The patient stated that the function of the hand had not been greatly improved but that she was able to hold things between the thumb and the fingers. Her condition was unchanged in August 1952, at which time she was working as a clerk.

FIG. 4-C

Axial Torsion Osteotomy of the Ulna

This osteotomy was devised by Milch for the treatment of a pronation contracture in which some supinator power was present and active rotation of the forearm was possible from complete pronation to the mid-position or just beyond. By a rotation osteotomy of

FIG. 4-D

Roentgenograms made June 7, 1949, showing the torsion of the radius. The radius is no longer angulated, since the ulna is now almost straight.

the proximal portion of the ulna, the arc of motion was shifted so as to restore some supination. This osteotomy can also be applied to a supination contracture.

Case 5. A Puerto Rican boy, one and one-half years old, had a very severe birth palsy and an unusual deformity of the left limb (Fig. 5-A) when he was examined on February 2, 1946. The shoulder was abducted 180 degrees and medially rotated 90 degrees. The elbow was acutely flexed, while the forearm appeared to be pronated. The wrist was adducted and flexed. The thumb was adducted and lay in the plane of the palm. The arm could not be brought to the side due to an abduction contracture of the shoulder of 35 degrees. There was a fixed medial rotation deformity of 30 degrees. The deltoid was strong but the pectoralis major was weak. The elbow could be extended passively to 150 degrees. The muscles arising from the medial epicondyle were atrophied. The forearm appeared to be pronated due to medial rotation of the shoulder but actually there was a supination contracture. Passive pronation was possible to the mid-position with "supination rebound" occurring on release. The flexed wrist dropped into dorsiflexion by gravity when the forearm was supinated.

Osteoclasis of the forearm was performed on November 29, 1946, and the forearm assumed the position of pronation. The arm was brought to the side of the body by cone osteotomy through the surgical neck of the humerus on December 9, 1946, and a plaster-of-Paris cast was applied in two sections. One section, applied first, extended from the upper portion of the arm to the upper portion of the forearm with the elbow at 90 degrees of flexion. When the shoulder was rotated to the neutral position, the forearm was found to be supinated. The forearm was then placed in pronation and held by the second part of the plaster cast which extended from the base of the fingers to the upper part of the forearm. It should be emphasized that osteotomy of the humerus should precede correction of the supination contracture of the forearm.

The supination contracture recurred even though a pronation brace was worn. Transverse osteotomy of the proximal portion of the ulna was performed in August 1950, and the forearm was rotated into pronation. The roentgenograms made October 17, 1950, disclosed non-union at the osteotomy site (Fig. 5-B), but the ulna was well united by February 1, 1951. At this time the shoulder was again held in medial rotation of 90 degrees. When the shoulder was brought to the neutral position, the forearm was pronated 40 degrees. There was no active power in the forearm, wrist, or hand (Fig. 5-C).

Mechanical Principles and Results of Torsional Osteotomy of the Radius

By means of torsional osteotomy of the radius, the distal fragment of the radius is pronated through a half circle while the proximal fragment remains supinated. The volar position of the ulnar head with relation to the radius is not changed by this maneuver, and a paradoxical relative displacement of the ulnar head exists postoperatively. (Normally, the ulnar head appears to be displaced dorsally when the forearm is pronated.)

Fig. 5-A

The radius angulates dorsally and medially as the distal fragment is pronated. There is always postoperative dorsal angu-

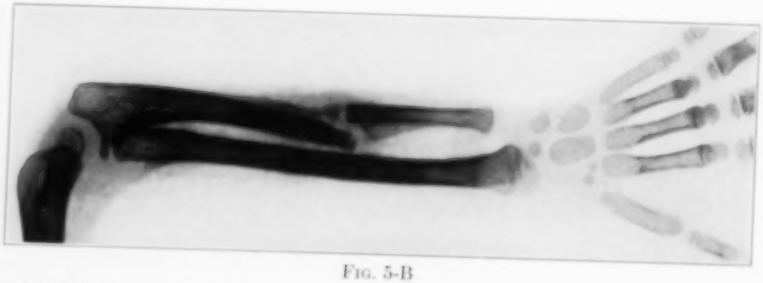

Fig. 5-B

Fig. 5-A: Preoperative photograph, January 31, 1946. *Left:* The habitual position of the left upper extremity. *Right:* The position of maximal correction with the forearm supinated.
Fig. 5-B: Roentgenogram made October 17, 1950, after osteotomy of the ulna.

FIG. 5-C

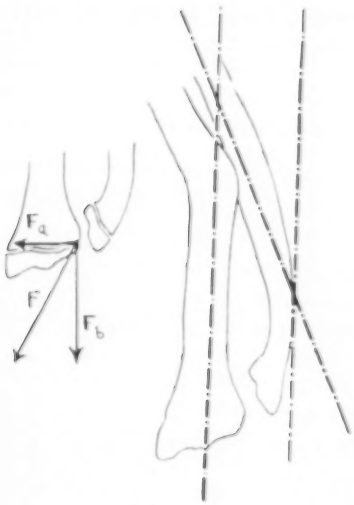

FIG. 6

Fig. 5-C: Photograph, February 1, 1951, showing the position of the forearm and shoulder. There was recurrence of the medial rotation deformity of the shoulder.

Fig. 6: Tracing of the roentgenogram reproduced in Fig. 4-B. The radius below the osteotomy site tilted medially until it was parallel to a tangent drawn through the point of maximal curvature of the ulna. The tilting of the radius is maximal when the ulna is bowed. *Fa* is the growth force of the lower radial epiphysis which increases its width, while *Fb* is the longitudinal growth force. *F* is the resultant of these two forces and is responsible for the bowing of the distal ulna. The change in the direction of the lower ulnar epiphysis further lessens its longitudinal growth.

lation of the radius. This is due to the paradoxical relative volar position maintained by the ulnar head. As the distal radial fragment is rotated into pronation, it rotates about its mechanical axis which extends between the osteotomy site and the distal end of the ulna, generating a cone. The result is that the distal end of the radius is displaced volarward as the forearm is pronated producing dorsal angulation at the osteotomy site. Medial angulation of the radius varies with the difference in length between the ulna and the radius. Angulation of the radius shortens it and the ulna becomes the longer bone. If, after operation, the radius approaches a length equivalent with the ulnar length, the medial angulation of the radius is minimal. The geometrical analysis of this was given in previous articles concerning congenital radio-ulnar synostosis and primary torsional fracture of the radius and ulna [3, 4].

Torsional osteotomy of a radius which is longer than the ulna should not cause angulation of the radius, for the effect of the torsion is to shorten the radius enough to restore length equivalence. Yet in the two cases in which medial bowing of the ulna was seen, the radius distal to the point of osteotomy angulated medially even though initially it was the longer bone. The distal segment of the osteotomized radius became parallel to the tangent drawn through the point of greatest curvature of the bowed ulna (Fig. 6).

The lower half of the ulna is medially and dorsally bowed (Fig. 4-B) when growth of its distal ulnar epiphysis is lessened as compared to that of the radius. This is sometimes the sequel of previous surgical intervention at the wrist. The ulna may be thought of as a cantilever beam. The free end, to which the force (the growth of the radius) is applied, is that part of the ulna which articulates with the radius distally. It is assumed that there are two components of this growth, that which lengthens the radius and that which broadens it. The force which bends the ulna is the resultant of these two forces. Finally,

the bowing of the ulna changes the direction of the lower ulnar epiphysis, further shortening the ulna.

After healing of the osteotomy of the radius, a certain amount of supination is still possible, even though the upper segment of the radius is fully supinated. However, the dorsal angulation of the radius after osteotomy and rotation into the pronated position blocks supination beyond the mid-position.

MECHANICAL PRINCIPLES AND RESULTS OF AXIAL TORSIONAL OSTEOTOMY OF THE ULNA

The *sine qua non* of this operation in which the ulna is twisted axially is a proximal radio-ulnar joint which is free to move. Section of the ulna creates a new paired-joint system, the mechanical axis of which is the line connecting the center of the head of the radius with the center part of the site of osteotomy in the ulna. This paired-joint system is temporary if the osteotomy is allowed to heal or permanent if a pseudarthrosis is maintained.

The more distal the site of osteotomy of the ulna, the more nearly does the mechanical axis of the new paired-joint system approximate the length of the physiological mechanical axis. Yet, the longer the distal fragment of the ulna, the greater is the moment which turns it for a given passive force applied to this distal fragment. The site of osteotomy should then be chosen by a compromise between these two factors, and it should be made as nearly as possible at the mid-part of the ulna.

SUMMARY

Supination contracture of the forearm, not uncommonly seen in Erb's palsy and occasionally seen in infantile paralysis, follows the selective palsy of the muscles arising from the medial epicondyle of the humerus. The supination deformity of the forearm is the primary link in a chain of deformities which consists in a triple deformity of the shoulder in flexion, abduction, and medial rotation, a flexion contracture of the elbow, and hyperextension of the wrist. The first step in correction is to return the shoulder to the neutral position. This must be done before correcting the supination deformity or the dorsiflexion of the wrist.

Operations used to relieve supination contracture of the forearm, especially osteotomy of the radius, are described. After section of the radius, there is dorsal and ulnar angulation of the radius by non-axial torsion of the distal fragment. The value of axial torsional osteotomy of the ulna to relieve supination contracture is noted.

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A Rational Approach to the Surgical Needs of the Cerebral Palsy Patient *

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This paper, the first of a general nature on surgery in cerebral palsy since McCarroll and Schwartzmann's report of 1943, is presented in the hope that it will stimulate renewed interest in a basic orthopaedic problem and bring about better care of this large group of patients. An attempt will be made to show the indications for and results that can be obtained from certain well known orthopaedic surgical procedures frequently used in poliomyelitis, but too seldom attempted in the treatment of the patient with cerebral palsy. The lack of application of these procedures to the patient with cerebral palsy is due, in part, to fallacies that have grown up around the use of surgery in the treatment of this disease. It is recognized that the results from surgery in cerebral palsy have not been, and will not be, as satisfactory or as predictable as they are in poliomyelitis. However, the surgical need of these patients has been overshadowed, as has often been true in poliomyelitis, by overenthusiastic exponents of so-called conservative therapy. Rehabilitation of the patient with cerebral palsy, as in all neuromuscular problems, depends on the restoration of muscle balance, the proper alignment of joints, and the establishment of correct posture with normal relationship to the line of gravity. If the program is directed at restoring ambulation, the patient should have sufficient sense of balance to help to maintain an upright position, with or without crutches, or braces, or both. At the North Carolina Cerebral Palsy Hospital and at Duke Hospital we have come to the conclusion that whenever uncontrolled spasticity or tension interferes with reaching these goals, one should not be reluctant to carry out necessary, properly selected surgery. When such surgery is indicated, in order to allow the rehabilitation worker to train the patient more easily and better, it should be carried out early in the therapy program. Many of the difficult problems encountered in the rehabilitation of the patient with cerebral palsy can be carried out more readily following surgical restoration of muscle balance and correction of deformities.

In previous papers on the triceps surae syndrome [1] and on surgery in cerebral palsy [2] it has been pointed out that when an overactive muscle is in need of correction, one must make a complete study of that muscle and its antagonists before deciding on the extent and method of correction. When the muscle is one with multiple action which influences more than one joint, the decision may be unusually difficult. The triceps surae and the tensor fasciae latae are good examples of this type of muscle. When surgery is to be done on one of these muscles, the component parts of the muscle and the intrinsic actions of each must be analyzed and evaluated as thoroughly as possible. In most instances, the surgery will be directed at correction of muscle balance, re-alignment of weight-bearing joints, restoration of control of these joints, and correction of posture. To bring about these changes, the aim of surgery may be directed at one or at a combination of any or all of the following: (1) decrease in spasticity, (2) elimination of clonus, (3) restoration of proper function of the muscle, (4) restoration of anatomical length, (5) decrease or control of overflow to the muscle, (6) decrease of overflow from the muscle, (7) correction of joint alignment, (8) restoration of joint function, (9) restoration of normal posture, (10) release

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TABLE I*

INTELLIGENCE QUOTIENTS ACCORDING TO DIAGNOSIS
(493 Cases)

Diagnosis	No. of Cases	IQ's Below 70 (*Per cent*)	IQ's Above 90 (*Per cent*)
Spastics	241	61	17
Athetoids	121	67	15
Mixed	53	62	13
Hemiplegics	69	56	15
Ataxics	18	49	50

* Psychological evaluation of 493 cerebral palsy patients seen at the North Carolina Cerebral Palsy Hospital. (Adapted from Hohman, L. B.: Intelligence Levels in Cerebral Palsied Children. Am. J. Phys. Med., **32**: 289, 1953.)

of tension, and (11) control of any involuntary motions resulting from overflow. McCarroll and Schwartzmann's emphasis on the importance of spastic paralysis and the allied disorders often confused with this malady is readily understood by their statement that in frequency it ranks second only to poliomyelitis in the average clinic for crippled children in this country. They also pointed out that many children are added to the list each year, a few of whom can be helped considerably, while many others show involvement to such a degree that little can be accomplished with treatment and little hope can be held out for their spontaneous improvement. They further state that the very nature of the condition is such that we will probably always be confronted with this problem; therefore, it behooves us to understand the problem as clearly as possible in order that we may offer the maximum of benefit to those patients with adequate prerequisites for treatment. Their report was based on 1,720 consecutive cases. Of their series of patients, only 437 (25.5 per cent) were considered suitable for surgery. In a previous paper [2] from the North Carolina Cerebral Palsy Hospital, based on a consecutive series of 977 cases, only 164 (16.7 per cent) were considered suitable for surgery. An additional twenty-two patients from other clinics had surgery. These figures should illustrate, if not prove, that this program has not been a radical one, but one wherein the benefits of surgery have been recognized and operative treatment used only when indicated.

One of the problems, not necessarily orthopaedic in nature but most important in all phases of the treatment of these patients, is the psychological potential of each patient. Table I, prepared from studies made by Hohman and his associates on this same group of patients shows the severity of this aspect of the problem.

As the benefits that can be derived from a well planned surgical program, followed by physical rehabilitation, have been observed, the approach has changed to one of relieving the patients of their disabling spasticity or tension and deformities by surgery, and then instituting the training program. It is now felt that the surgical corrections should be carried out as early as feasible and should be directed at preventing bad locomotion habits. As a result of the normal development which takes place in the undiseased portions of the central nervous system, the paralysis from these irreparable central-nervous-system lesions usually shows spontaneous improvement. Much of the benefit that has been attributed to corrective splints, braces, exercises, and other measures carried out in long drawn-out, expensive treatment programs, has in many instances come from these natural processes of development. This improvement is observed in patients who have never had therapy. If uncontrolled spasticity and tension can be relieved early by surgery or otherwise, such improvement can occur more readily. Many of the problems in the patient with severe cerebral palsy are complex, particularly in those cases in which surgery may be indicated. In a severely involved non-ambulatory patient (Fig. 1), there may be a combination of: a spastic valgus deformity of the fore-part of the foot, a broken-down longitudinal arch with

severe pes planus, an eversion of the calcaneus, and an equinus deformity at the ankle. In turn, there may be valgus and flexion deformity at the knee associated with a combination of a tight spastic gastrocnemius, spastic hamstrings, and a contracted fascia lata (Fig. 2). Further, there may be spasticity in the quadriceps which, in combination with the spastic flexors, results in a stretching of the patellar tendon. This type of patient usually presents adduction deformities at the hip, associated with flexion internal rotation of the femur. These changes, complicated by weak overstretched abdominal and gluteal muscles, result in an anterior tilt of the pelvis and an increased lumbar lordosis.

FIG. 1

A non-ambulatory patient with spastic cerebral palsy. Typical deformities are bilateral spastic valgus deformities of the fore part of the foot, broken longitudinal arches with severe pes planus, eversion of the calcaneus, and bilateral equinus deformity at the ankle. The tibiae are externally rotated and the knees are fixed in flexion associated with bilateral contracture of the fascia lata and severe flexion deformities of the hips with internal rotation of the femur.

In the patient with these complex weight-bearing-joint deformities, it is always difficult to determine which deformity is primary in nature and which one or more are compensatory. Each of the deformities may be an entity within itself, or, instead of being compensatory or primary, they may be the result of overflow. As stated above, surgical correction in this type of patient should be carried out early, preferably in the pre-ambulatory stage, before the child has formed bad locomotion habits. Far too many of these children are seen after fixed deformities, permanent contractures, and bone and joint changes have occurred. Surgical relief should be attempted only after complete evaluation of all the components involved. The component that is thought to be primary should be the first to be corrected.

Foot Deformity

The major foot deformity seen in such a patient, in most instances, has resulted from spasticity, tension, or shortening of the triceps surae. The valgus deformity of the foot may be the result of an overlooked spasticity or tension in the peronaeus longus or brevis muscles. Usually associated with these changes one will find a non-functioning tibialis anterior and a stretched-out tibialis posterior. If no structural changes have occurred, this type of valgus deformity can, in some instances, be corrected by a transplantation of one of the peronaeus tendons to the tibialis posterior. When the peronaeus longus is used, the distal stump should be sutured into the tendon of the peronaeus brevis. Such a transplantation combined with a triceps surae lengthening, can produce a balanced foot and possibly avoid subtalar stabilization. The operation has the advantage of being reversible. In a previous paper [1], the various procedures available for correcting triceps surae involvement have been covered. As stated in that paper, we are inclined to do fewer and fewer neurectomies in order to correct dysfunction in these muscles. If lengthening is indicated in the calf group, surgery in most instances is confined to a lengthening of the aponeurosis of the gastrocnemius, with the soleus fibers dissected from the distal portion of the aponeurosis (Fig. 2). The technique is similar to that described by Vulpius, but

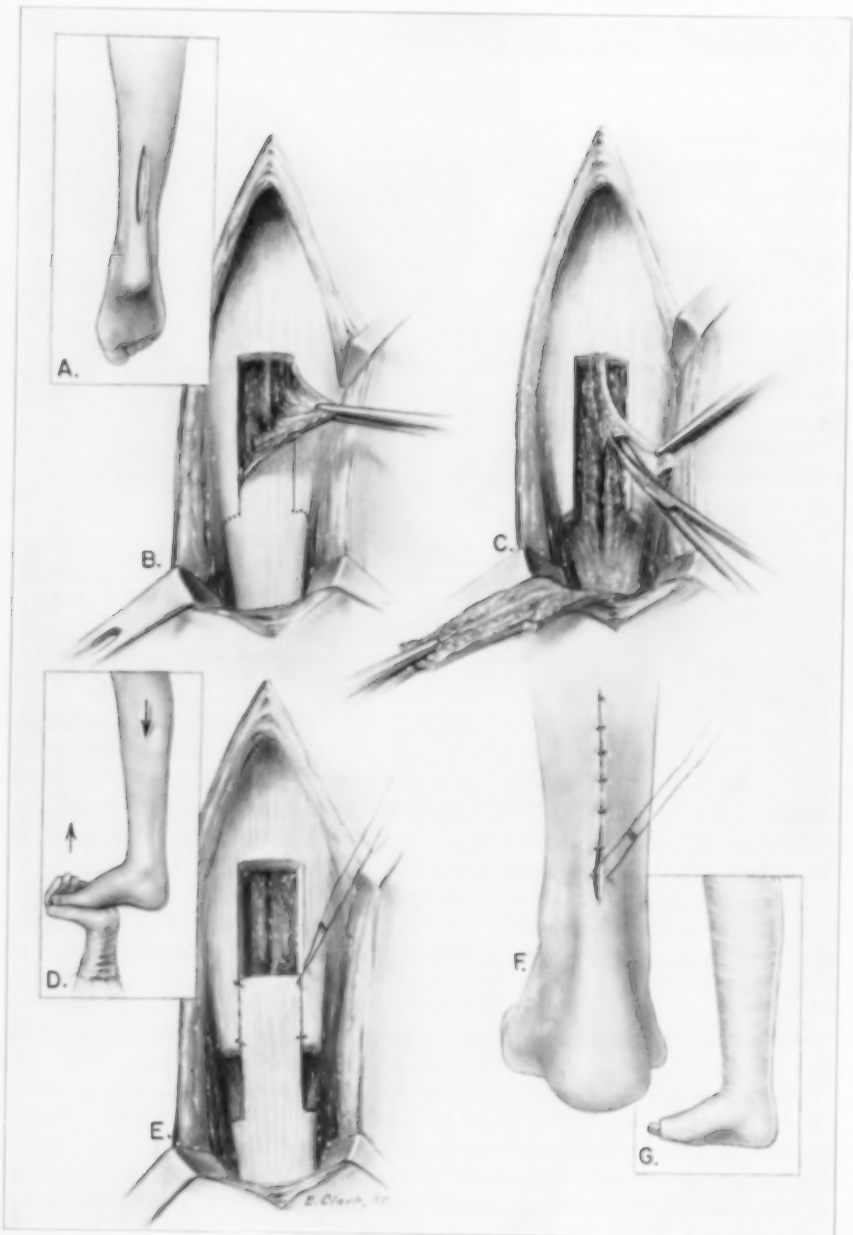

FIG. 2

Technique for lengthening the aponeurosis of the gastrocnemius muscle: *A*. The incision extends from the lower border of the belly of the gastrocnemius muscle to the proximal end of the Achilles tendon. *B*. An inverted U incision is made through the aponeurosis, the lateral and medial portions remaining intact with underlying soleus muscle. The middle portion, or tongue, is dissected from the soleus, care being taken that no muscle fibers remain attached to this portion of the aponeurosis or to the Achilles tendon. *C*. Dissection of the central aponeurosis of the bipenniform soleus muscle. *D*. Dissection is carried out sufficiently to allow full dorsiflexion of the ankle. *E*. The distal attachments of the lateral and medial portions of the aponeurosis are freed from the tendon; the four corners of the overlapping portions of the aponeurosis are held with one black-silk suture each. *F*. Following closure of the deep fascia and the subcutaneous fascia, the skin is closed with intra-

cutaneous sutures. *G.* Extremity is incorporated in a toe-to-groin cast with the foot placed in slight dorsiflexion. When this type of lengthening is carried out for the correction of postpoliomyelitic contractures, the soleus fibers are not dissected from the distal tongue, except as may be necessary in order to accomplish the desired lengthening. If the soleus is not dissected in the presence of spastic cerebral palsy, stretch reflex will result in clonus.

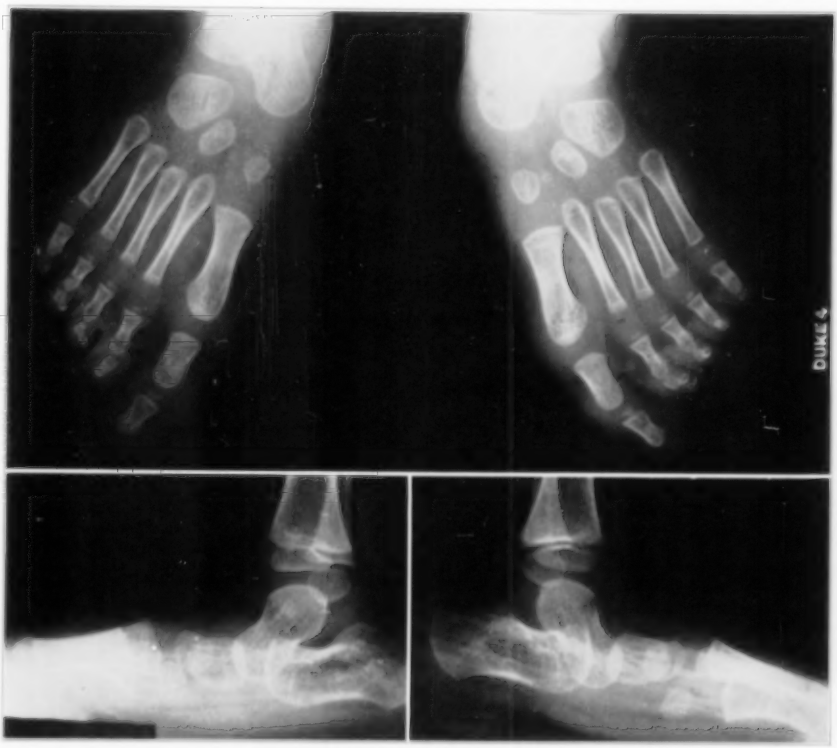

FIG. 3

Roentgenograms of severe bilateral eversion of the calcaneus, showing fixed equinus deformity of the talus with resultant rocker-soles and valgus deformity of the forepart of the foot. These roentgenograms illustrate the type of foot which is amenable to correction by lengthening of the aponeurosis of the gastrocnemius combined with the Grice operation.

varies in that it allows a lengthening with the soleus detached from the distal portion of the fascia and tendon, thus eliminating any tendency toward stretch reflex which in turn avoids clonus. The incision extends from the lower border of the belly of the gastrocnemius muscle to the proximal end of the Achilles tendon. An inverted U incision is made through the aponeurosis. The lateral and medial portions remain intact, with the underlying soleus muscle. The middle portion, or tongue, is dissected from the soleus, care being taken that no muscle fibers remain attached to this portion of the aponeurosis or to the Achilles tendon. Complete dissection of the muscle fibers from the distal portion of the lengthened structure will avoid residual stretch reflex and clonus. The distal attachments of the lateral and medial portions of the aponeurosis are then freed from the tendon. Dissection is carried out sufficiently to allow full dorsiflexion of the ankle. The central aponeurosis of the bipenniform soleus muscle should, if necessary, be sectioned or dissected as this fibrous band frequently extends distally and may interfere with complete correction. The four corners of the overlapping portions of the aponeurosis are held with one black-silk suture each. The extremity is incorporated in a toe-to-groin cast, with the foot placed in slight dorsiflexion. The operation allows adequate correction. It avoids damage to the tendon sheath, and has a better placed incision with adequate subcutaneous tissue

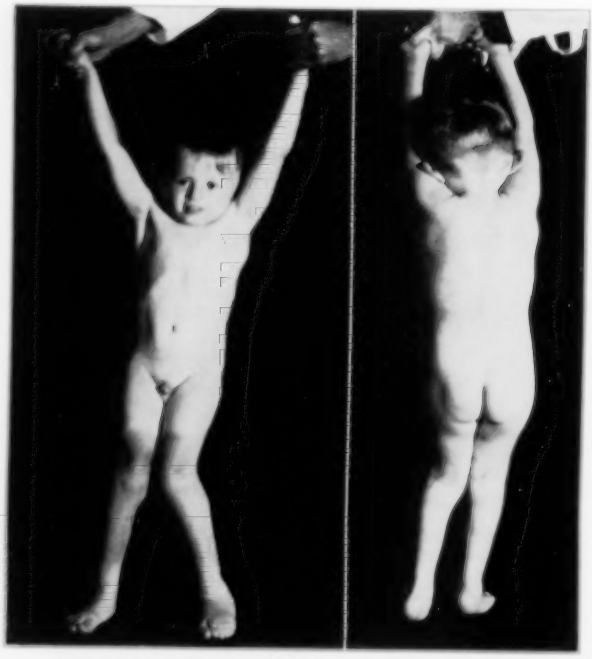

Fig. 4

Fig. 4: A young, non-ambulatory spastic cerebral-palsied patient with changes as illustrated in Figs. 1 and 3.

Fig. 5: Same patient as in Fig. 3 following release of the gastrocnemius heads and Grice bone-block.

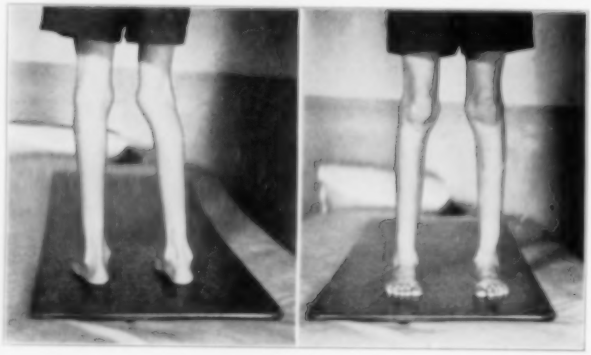

Fig. 5

to avoid skin adhesions, such as are frequently seen when the tendon itself is subjected to surgery. In those cases in which eversion of the calcaneus has occurred (Fig. 3), the talocalcaneal bone-block procedure described by Grice, which as he has shown will stabilize the subtalar joint in good position in the flail foot and in the flaccid type of flat-foot, has been found to be equally satisfactory in the patient with cerebral palsy (Figs. 4 and 5). Gratifying results have also been seen following talocalcaneal blocking by the Chambers' technique with added bone graft. Likewise, the pes planus deformity (Fig. 6) can be nicely corrected (Fig. 7) by the technique described by Miller. In all instances in the patient with cerebral palsy in whom any of these procedures have been carried out for correction of pes planus, a lengthening of the triceps surae is required. In each of the stabilizing procedures, if the peroneals are spastic, either lengthening or transplants are indicated. Neurectomies of the peroneals have not been tried by us, but may possibly be indicated in some patients.

Knee-Flexion Deformity

In evaluating knee-flexion deformity, the part played by the gastrocnemius and that played by the hamstrings must be determined by standard tests. Surgery is then directed at correcting the deforming force. In those instances in which the gastrocnemius is involved, either a lengthening of the aponeurosis as described above or a release of the origin of the muscle from the condyles of the femur and from the posterior aspect of the capsule of the knee joint may be considered. If it is necessary to correct flexion, one of these procedures can be combined with lengthening or tenotomy of the hamstrings. The operation for release of the origin of the gastrocnemius (Fig. 8) can be best carried out through a hockey-stick, transverse incision across the lower portion of the popliteal space, the

superficial nerves being preserved and followed to their origin from the posterior tibial nerve. The proximal portion of the origins of the two heads of the gastrocnemius are easily identified, as are the peroneal nerve and the hamstring tendons. The procedure is not difficult. In carrying it out, one must be certain that the exposure extends far enough medially and laterally to allow release of the medial and lateral expansions of the muscle which pass well around anteriorly to form tendons of origin. Exposure of these tendinous origins of the muscle, especially of the lateral head, can be better facilitated than is illustrated in Figure 8 by retracting the hamstring tendons inward toward the popliteal space. This approach to the lateral head avoids unnecessary traction of the peroneal nerve. Sharp dissection is necessary only to incise the strong tendinous bands of origin that lie medially and laterally. The muscular origin from the posterior aspect of the femur and from the capsule of the knee joint, in the main, can be bluntly reflected with the handle of a scalpel.

FIG. 6

Severe pes planus in patient with spastic cerebral palsy.

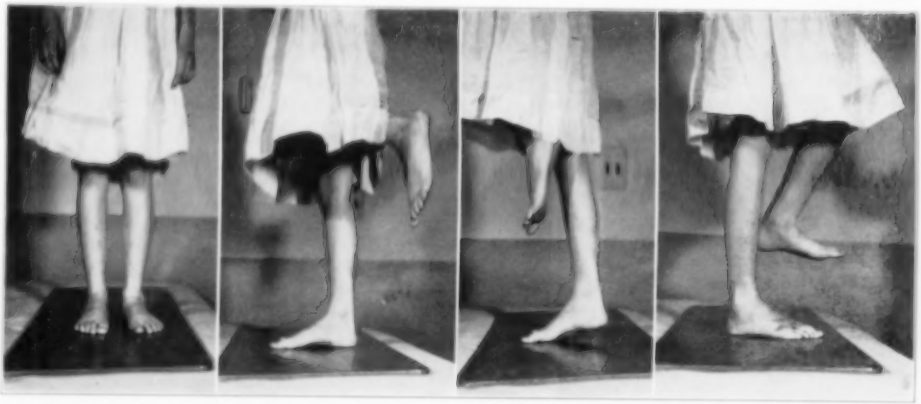

FIG. 7

Same patient as in Fig. 6 following a Miller longitudinal-arch stabilization and gastrocnemius-aponeurosis lengthening.

Green and McDermott, in describing division of the iliotibial band in conjunction with lengthening of the hamstrings, recommended the division of these tendinous origins of both heads of the gastrocnemius. If, after such surgery directed at releasing flexion deformities of the knee, the patient cannot actively extend the joint to 180 degrees, one should not hesitate to transplant the insertion of the patellar tendon distally on the shaft of the tibia, either by the Chandler procedure or by modifications thereof in which the tendon itself is transplanted without a block of bone being removed (Fig. 9). The tendon is anchored distally beneath an osteoperiosteal trap by means of a metal screw and silk

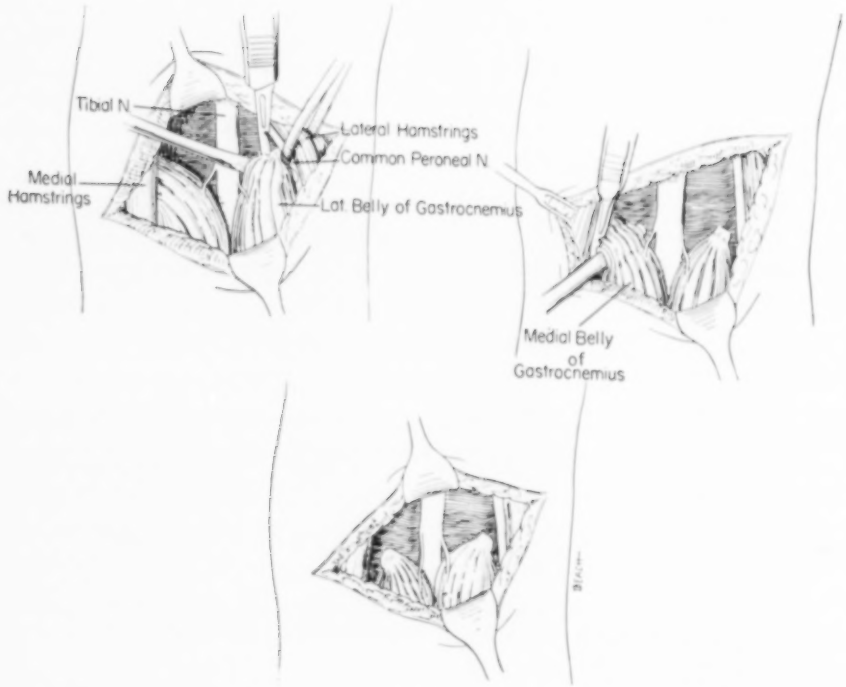

FIG. 8

Technique for release of the origins of the gastrocnemius. Courtesy, Archives of Surgery. (Reproduced by permission from Baker, L. D.: Triceps Surae Syndrome in Cerebral Palsy, *A.M.A. Archives of Surgery*, **28**: 220, 1954.)

sutures. The principal advantage of this method is that the procedure allows transplantation of the tendon without injury to the epiphysis; this allows the operation to be done in a younger patient. The technical advantage of an easier technique and therefore shorter operation time and less postoperative discomfort are desirable points.

Hip-Flexion Deformity

Without full knee extension on weight-bearing, compensatory hip-flexion deformity cannot be avoided. The latter is one of the most difficult deformities to analyze and to correct. Knight has emphasized the necessity of differentiating flexion internal rotation deformity from simple adduction flexion deformity. The tensor fasciae latae is at fault in most of the cases that present flexion internal rotation deformity. Many of these patients, as a result of an area-four involvement, may present flaccid paralysis, particularly of the gluteals, abdominals, and abductors of the hips. Such weakness is not necessarily central in origin, but may be due to overstretching and long disuse. Phelps has pointed out the advantages to be derived through procaine infiltration into the spastic antagonists in order to differentiate true flaccid paralysis from weakness due to overstretching and disuse and to determine the presence or absence of potential function in these non-functioning muscles. If, after such studies, it is found that the patient can bring the weak muscles into play, release of the spasticity or tension in the antagonist will contribute materially to the possibility of redeveloping balanced power. This redeveloping program is more likely to be successful in the younger group in which correction has been carried out before fixed fascial contractures and joint deformities have occurred. In the poliomyelitic patient with contracted tensor fasciae latae and beginning pelvic obliquity, orthopaedists do not hesi-

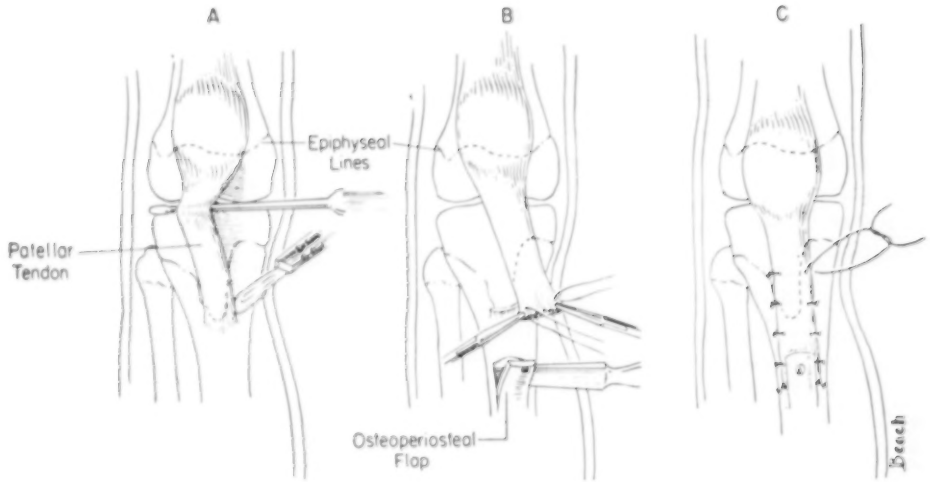

FIG. 9

Modification of the Chandler procedure for transplanting the insertion of the patellar tendon. The tendon itself is transplanted without a block of bone being removed, the tendon being carefully dissected from the tibial epiphysis and anchored distally beneath an osteoperiosteal trap by means of a metal screw and silk sutures.

tate to carry out corrective measures. Such measures are equally as important in the patient with cerebral palsy. In most instances, the tensor fasciae latae is the chief offender in the flexion internal rotation deformity of the hip. The Yount release of the tensor fasciae latae may be sufficient to correct the internal rotation deformity at the hip and in turn can be used to prevent and correct the frequently seen valgus and rotation deformity at the knee. In most instances, the procedure will have to be combined with a partial neurectomy of the obturator nerve and with tenotomy of, at least, the adductor longus and gracilis. In carrying out the Yount procedure in this group, as in poliomyelitis, the operator should use particular care to see that the intermuscular septum from the tensor fasciae latae is freed from its insertion into the femur. Following the above-described procedures, all of which, with two teams working, can be carried out at one time, the lower extremities should be incorporated in corrective toe-to-groin plaster casts as described by Irwin in his correction of tensor fasciae latae contractures.

Postoperative Care

When only tendon and muscle surgery has been done, the extremities are kept in casts for four to six weeks, or longer if indicated. Wedging of the cast for further correction may be carried out as needed. If the bone-block procedures have been done, the foot is immobilized for ten weeks. Later, if necessary, braces with any indicated ankle, knee, or hip locks, or pelvic bands may be used. If the surgery has been well chosen, and muscle balance has been restored, the patient should eventually be brace-free, but may need crutches.

Barr has described a procedure for the tensor fasciae latae and has pointed out the danger of doing simple myotomies in this complex muscle. In a previous paper [1], we described a modification of the Barr procedure in which a transplantation of the anterior origin of the oblique fibers of the muscle is done. We have found it ill-advised to detach the lateral origin of the vertical fibers. The anterior fibers are freed from the ilium, as well as the origin of the glutaeus minimus, if indicated, care being taken not to interfere with the nerve innervation or the blood supply. The anterior borders of the two muscles are then threaded with multiple end-on mattress sutures, the free ends of the sutures pointing medially. The upper sutures are passed up under the lateral portion of the muscle and are

TABLE II

TYPES OF OPERATIONS *

Neurectomies		158
Obturator (anterior branch)	116	
Gastrocnemius	22	
Soleus	15	
Pronator teres	1	
Popliteal	4	
Tenotomies		279
Adductors	120	
Achilles	43	
Hamstrings	42	
Iliotibial band	12	
Gastrocnemius fascia	55	
Posterior tibialis	2	
Glutaeus minimus	1	
Hand (intrinsic)	1	
Biceps humeri	1	
Plantar fascia	2	
Muscle-origin releases		66
Gastrocnemius	54	
Tensor fasciae latae	5	
Hip flexors	7	
Tendon transplantations		45
Hand	12	
Anterior tibialis	7	
Pronator teres	12	
Patella	6	
Tensor fasciae latae	2	
Extensor hallucis longus	3	
Peronaeus longus	3	
Arthrodeses		27
Wrist	10	
Subtalar	10	
Miller procedure	3	
Metacarpophalangeal joint (hand)	4	
Sinus tarsi blocks		8
Osteotomies		5
Femur	3	
Tibia	2	
Pedunculotomies		2
Total operations		590

* The above statistics are the actual number of procedures performed; that is, when a procedure is done bilaterally, it is counted as two operations. If two procedures are done through the same incision, such as an adductor longus lengthening and a neurectomy of the obturator nerve, they are counted as two procedures. Each tendon transplant in the hand is counted as a procedure, although many of them are done at the same time. Five hundred and ninety procedures were carried out in a total of 186 patients, 164 of the patients coming from the North Carolina Cerebral Palsy Hospital, and twenty-two from other sources[2].

sutured through a trap in the pelvis. The lower sutures are passed laterally and backward under the remaining portion of the tensor fasciae latae, are brought out between the tensor fasciae latae and the glutaeus maximus through the intermuscular septum, and are tied. As the sutures are pulled through and tightened, the anterior borders of the two dissected muscles are rolled under the remaining portion of the tensor, where they are fixed. From our experience, both the myotomies and the transplants should be avoided when at all possible, as results, although sometimes satisfactory, may be most disappointing. The same is true, as pointed out by Knight, of the Durham procedure.

If there remain flexion deformities of the hip, further surgery for release of the rectus

femoris and for release of the iliopsoas muscle may be necessary to obtain full extension of the hip and to allow the patient to develop his gluteal and abdominal muscles, which play such an important role in the upright posture.

SUMMARY

This paper, as stated in the introduction, is presented to redirect attention to a primary orthopaedic problem; to describe techniques to correct triceps surae dysfunction; to emphasize the importance of correcting deformities caused by spasticity or tension in the tensor fasciae latae; to point out deformities in the foot which can be corrected and controlled by the Grice bone block; and to emphasize the importance of correcting all deformities before instituting rehabilitation in the cerebral palsy patient.

The examination of 977 cerebral palsy patients at the North Carolina Cerebral Palsy Hospital and an uncalculated number in associated clinics from February 1950 to May 1954 has afforded an opportunity to evaluate many cerebral palsy problems. The opinions expressed are based on the results seen following 590 operative procedures carried out in 186 patients. The type of surgery performed is shown in Table II. With the present widespread and professional lay interest in cerebral palsy, it is hoped that these and other well established orthopaedic surgical procedures can be used to the benefit of the cerebral palsy patient, and that new procedures will be developed that will further advance surgery in this difficult field.

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Immunological Factors in Homogenous-Bone Transplantation *†

II. Histological Studies

BY PAUL H. CURTISS, JR., M.D., SAMUEL W. CHASE, PH.D., AND CHARLES H. HERNDON, M.D., CLEVELAND, OHIO

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The results of serological studies on immunological factors in homogenous-bone transplantation [1] showed that although transplanted dog bone or its contained cellular elements appeared to act as an antigen, no relationship between that antigen and the "blood type" of the donor dog could be established with certainty. The following experimental work was done in an attempt to ascertain if histological evidence could show any such relationship.

METHOD

The presence of distinct groups of antigenic substances in the red blood cells of dogs, as demonstrated by Young and his colleagues, has been previously discussed [1]. In these histological studies, as in the serological studies, the basic research premise was that the most potent of these antigens, the canine A factor, is capable of producing anti-A antibodies. By means of anti-A typing serum, a large number of dogs of approximately the same age and weight were typed ** to find ten pairs, one dog in each pair being A-positive and the other being A-negative. The term "A-positive dog" does not mean however that the red blood cells of the dog contained the canine A factor alone, since the A factor rarely occurs alone; and it is certain that the red blood cells of an A-negative dog, although not containing the A factor, do contain one or several of the other factors,—that is, the B, C, D, or E factors. "A-positive" and "A-negative" simply indicate the presence or absence of the A factor in the red blood cells.

The A-negative dog of each pair was injected intravenously twice weekly with 5.0 cubic centimeters of citrated whole blood from its A-positive partner. After the first two weeks, serum from the blood of the recipient A-negative dog was titrated at weekly intervals for the development of anti-A agglutinins ***. When there was agglutination in the 1:256 dilution (and only rarely did it not develop), grafting procedures were carried out. The A-negative dogs in which the grafts were left for the longer terms were given a booster dose of 5.0 cubic centimeters of citrated whole blood from the companion A-posi-

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** *Blood typing for canine A factor:* 5.0 cubic centimeters of whole blood in a clean dry tube is allowed to clot. The coagulated blood is loosened and then centrifuged to free the serum. The clot is washed with saline, removed from the tube, and centrifuged in saline in order to pack the cells. A 3 per cent cell suspension in a solution of 50 per cent autogenous serum and 50 per cent normal saline is made by adding .03 cubic centimeter of the packed cells to a solution composed of 0.5 cubic centimeter of autogenous serum and 0.5 cubic centimeter of normal saline. Then 0.1 cubic centimeter of the 3 per cent cell suspension of the dog to be tested is placed in a small serology tube with 0.1 cubic centimeter of anti-A typing serum. The tube is gently agitated. The mixture is allowed to stand at room temperature for fifteen minutes and then is centrifuged for one minute at 1,500 revolutions per minute. The tube is shaken gently and the serum mixture is examined for agglutination. If there was evidence of agglutination, the type was A-positive, and if there was no agglutination the type was A-negative.

*** *Titration for development of anti-A agglutinin:* A 3 per cent red-blood-cell suspension was prepared

tive dog monthly; the anti-A titer was checked regularly and if it had fallen below 1:256, it was raised by repeated increments of 5.0 cubic centimeters of whole blood from the paired A-positive dog.

After anti-A agglutinins *** had developed in the A-negative dog, the following series of grafts were done. Each dog of the series received three bone grafts consisting of segments of iliac bone placed in the right and left ulnae, in which defects had been produced by segmental resection of approximately one inch of the ulnar shaft. The grafts were secured in position by wiring through drill holes at each end of the graft (Fig. 1). The location and types of the grafts were as follows: distal portion of the right ulna, an autogenous graft; proximal portion of the right ulna, a homogenous compatible graft from a dog of the same blood type; left ulna, a homogenous incompatible graft from a dog of opposite blood type,—that is, A-positive bone into an A-negative dog and *vice versa*. Roentgenograms of each dog were made at regular intervals. The animals were sacrificed in pairs and the grafts were recovered at the following intervals: three days, seven days, two weeks, one month, two months, three months, four months, six months, eight months, and twelve months. The recovered grafts and the adjoining sections of host bone were then sectioned and studied microscopically.

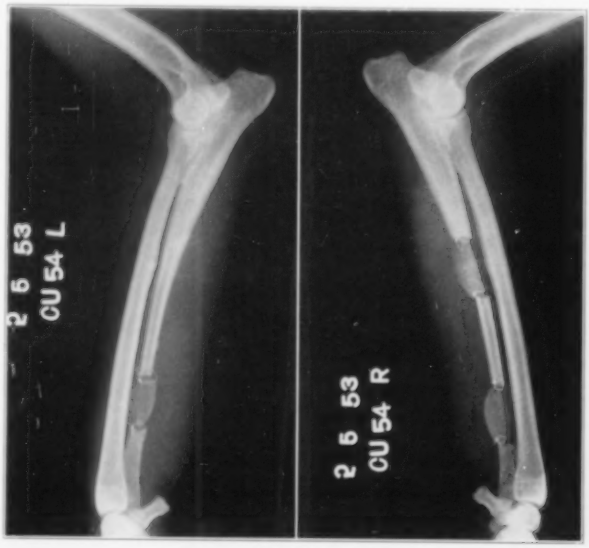

FIG. 1

Roentgenograms showing the way in which iliac grafts were placed in ulnar defects.

RESULTS

Roentgenographic Findings

Study of the serial roentgenograms of the grafts demonstrated only the usual findings of varying degrees of incorporation or of absorption of the bone graft. In some instances, solid bony union of the ulnar shaft with both ends of the graft was seen, while in others there were varying degrees of absorption of the graft. The findings will not be reported in detail as they parallel very closely the microscopic findings.

Microscopic Findings

In studying the histological sections, the grafts and host bone were examined with respect to the following: (1) the degree and type of union of the graft and the host, (2) the viability of the graft cortical bone, (3) the viability of the graft cancellous bone, (4) the viability of the marrow elements of the graft, and (5) the degree of connective-tissue replacement of the graft. As seen in Table I, numerical values were assigned to the microscopic findings in each category. This is, admittedly, an arbitrary method of evaluat-

from the blood of the donor A-positive dog in 50 per cent autogenous serum and 50 per cent normal saline. The sera of the recipient A-negative dogs were made up in two-fold dilutions to 1:512. Then 0.1 cubic centimeter of the 3 per cent red-blood-cell suspension was added to 0.1 cubic centimeter to each dilution of serum, mixed gently, and allowed to stand fifteen minutes at room temperature. The tubes were then centrifuged for one minute at 1,500 revolutions per minute and examined for agglutination.

TABLE I

GRADING OF GRAFTS

Microscopic Findings	Numerical Value
Union	
None	0
Fibrous	2
Fibrocartilaginous	4
Bony	6
Viability of cortical bone	
None viable	0
Less than 50 per cent viable	2
More than 50 per cent viable	4
100 per cent viable	6
Viability of cancellous bone	
None viable	0
Less than 50 per cent viable	2
More than 50 per cent viable	4
100 per cent viable	6
Viability of marrow elements	
None viable	0
Less than 50 per cent viable	2
More than 50 per cent viable	4
100 per cent viable	6
Connective-tissue replacement of graft	
Complete replacement	0
More than 50 per cent replacement	2
Less than 50 per cent replacement	4
No connective-tissue replacement	6

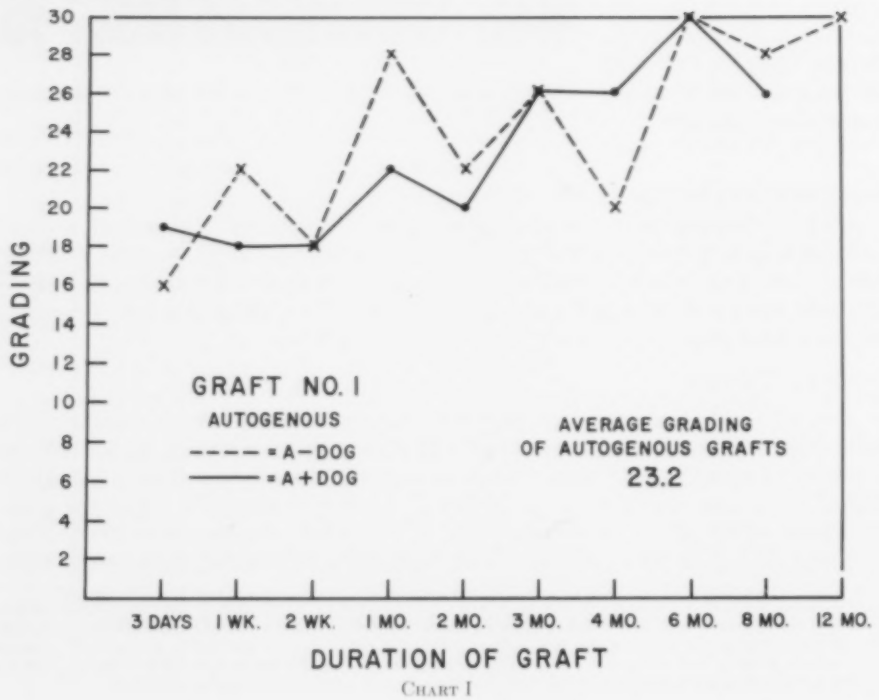

CHART I

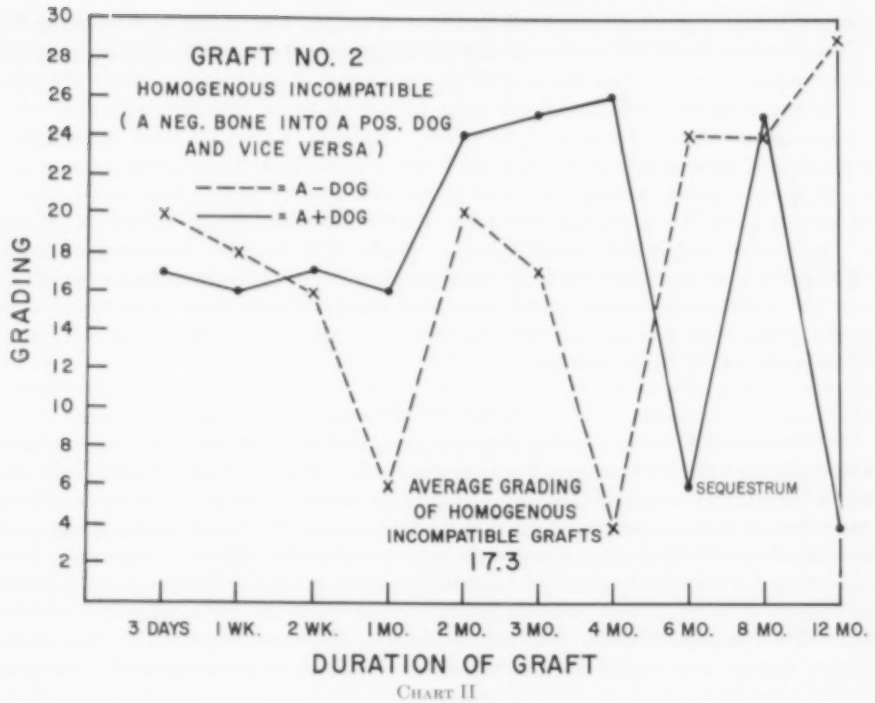

CHART II

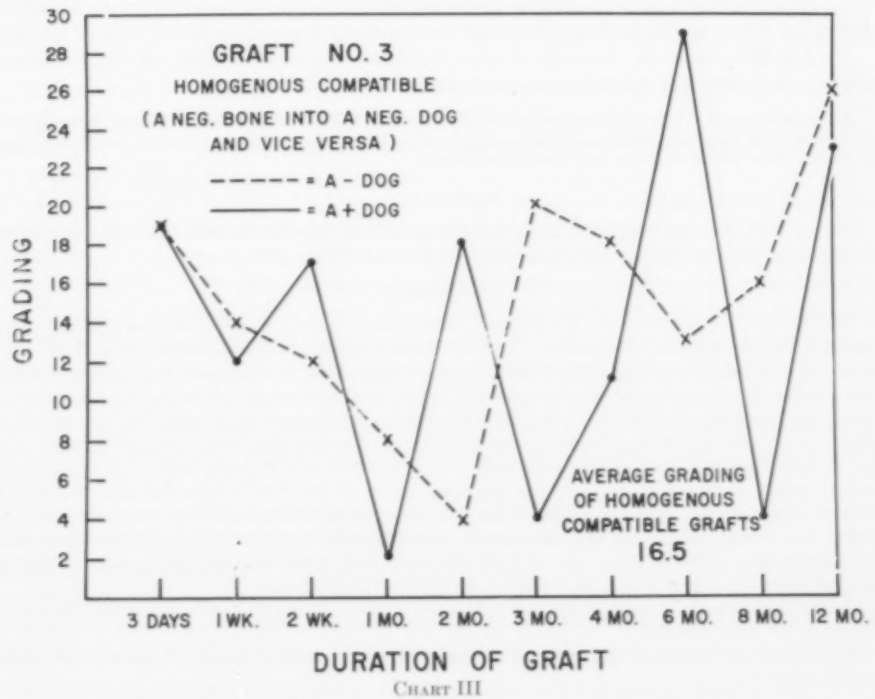

CHART III

ing a graft, but it gives an index which allows a standard comparison between grafts.

Study of the grafts did not reveal any strikingly new findings. The picture in general was the well known one of an iliac graft in various stages of replacement, either of acceptance by the host with union and new-bone formation, or of rejection with non-union, absorption, and connective-tissue replacement. Charts I, II, and III show the results of the grading of these grafts in the different time periods. It is immediately evident that the autogenous grafts (average grade 23.2) did consistently better than either type of homogenous graft. In comparing the latter, there was no significant difference between the homogenous compatible grafts (average grade 17.3) and the homogenous incompatible grafts (average grade 16.5). If the difference in blood type had had a significant effect, the incompatible grafts would have been markedly inferior to both of the other types of grafts. This was not the case; the host tolerance for the compatible and incompatible grafts was virtually the same.

DISCUSSION

Pertinent references to the literature on the relationship of blood groups to homotransplantation have been made in Part I of this study [1]. The histological findings reported here do not produce any evidence to suggest that a known blood-group antigen-antibody antagonism (A and anti-A) has any demonstrable effect on the fate of an iliac-bone graft. The method used in this study, however, is only one of several different techniques which could have been used in the study of immunological factors in bone homotransplantation. The authors do not feel that their findings eliminate these factors as playing a role and believe that considerable work remains to be done to eliminate the possibility that immunological factors may contribute to the success or failure of a homogenous bone graft.

CONCLUSIONS

1. In these experiments, known incompatibility of blood types had no demonstrable histological effect on the healing of homogenous or autogenous iliac-bone grafts in the dog.

2. Autogenous grafts showed consistently better response to grafting than did compatible or incompatible homogenous-bone grafts.

ACKNOWLEDGMENT: Through the kindness of Dr. Lawrence E. Young and Dr. William A. O'Brien of the University of Rochester Medical School, a supply of anti-A serum was obtained which was used to type and classify dogs into A-positive and A-negative groups.

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DISCUSSION

DR. ROBERT D. RAY, SEATTLE, WASHINGTON: The authors have clearly demonstrated that in dogs the response to fresh homografts of bone differs from the response to fresh autogenous-bone grafts. A difference can also be demonstrated in rats. Slides illustrating the implantation of autogenous and homogenous bone in the anterior chamber of the rat eye were presented. Histological sections of the *autografts* showed evidence of new-bone formation. On the other hand, histological sections of *homografts* of adult rat bone revealed a varied type of cellular reaction, including plasma cells, lymphocytes, fibroblasts, and foreign-body giant cells. In rare cases, the graft appeared to survive for prolonged periods. More commonly, it underwent eventual resorption. However, *homografts* of embryonic rat bone survived in most instances and showed abundant new-bone formation. No claim is made that the foregoing findings are new. A homogenous-tissue reaction, or a foreign protein cellular inflammatory incompatibility reaction, to homografts of fresh adult bone has also been shown by others, including Wickstrom and Mosiman[b] and Bonfiglio and Jeter[a]. Enough work has now been done so that a few tentative conclusions can be drawn:

1. The response on the part of the host seems to be related to inbreeding or rather to a lack of inbreeding of the animal strain.

2. The reaction to fresh, living homografts apparently is more marked than the reaction to non-viable, frozen homografts.

(Continued on page 336)

Tibioperoneal Tenoplasty for Congenital Club-Foot with Peroneal Insufficiency *

BY JUAN FARILL, M.D., MEXICO, D. F.

Heredity, postural defects *in utero*, embryogenic malformation, and muscular imbalance are the factors most often mentioned in etiological studies of congenital club-foot. Special attention has been given lately to muscular imbalance due to defects in tonus; and Brockman, Camera, Compere, Garceau, Gourdon, Lelievre, Lombard, and Steindler, among others, have stressed the importance of this factor in the pathogenesis of club-foot.

"The true clubfoot in which there is pronounced muscular imbalance," Compere says, "is a primary germ cell defect that may be repeated several times in the same family". It "cannot be explained on the basis of a mechanical process or abnormal position", being "produced because certain muscles are overactive, pulling the foot out of position, and the opposing muscles are kept overstretched until they become weak and unresponsive".

In some patients club-foot has its origin in a primary developmental variation of the skeleton; and in others it is symptomatic of a true paralytic imbalance, such as is seen in *patients with spina bifida. For patients in whom there is no sign of a true developmental* variation or of a paralytic condition, however, the author accepts muscular imbalance as the most logical hypothesis.

At the XXVI Congresso Della Società Italiana di Ortopedia e Traumatologia, Camera pointed out that only 20 to 25 per cent of late results could be considered satisfactory. He claimed that muscle imbalance, as shown in the movements of the foot, is the cause of the deformity; and for that reason since 1932, he has performed tendon transplantations in patients with club feet.

Garceau has emphasized the importance of muscle imbalance, incoordination, and fibrosis and has said that the primary pathological changes appear to be in the muscles, tendons, fascia, and joint ligaments. He devised his technique of tendon transplantation for use in selected cases of club-foot.

Pierre Lombard does not consider club-foot as a true malformation but rather considers it to be the result of muscle imbalance, which is due not only to paralysis but also to hypotonicity and hypertonicity of the muscles. The peripheral-nerve cell may not be absent or destroyed but often appears to be malconnected or non-connected with the extrapyramidal and the pyramidal systems, which no longer influence the action of the muscles. He states that the deformity appears in conjunction with the first manifestations of muscle tonus, that is, at about the eighteenth week of intra-uterine life. Before birth the deformity is increased by movements of the foetus, and after birth the muscle imbalance is exaggerated as voluntary motility, originating in the pyramidal tract, reinforces the muscle tone, stretching some structures and shortening others, including the muscles, ligaments, tendons, and fascia.

Gourdon agrees with Lombard and cites Atha Thomas, who used electrical methods to examine newborn infants with club feet, demonstrating that the muscular excitability in the legs of these infants was normal except in the peroneal muscles; the peronaei always reacted, but quantitatively they reacted less than did the other muscles of the foot. The bony changes in club-foot are secondary to the muscle imbalance; as is expressed in Delpech's law, osteogenesis increases when the bony surfaces are abnormally decompressed.

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 20, 1955.

FIG. 1

Fig. 1: Tibioperoneal tenoplasty. The dotted line shows the plantar course of the peronaeus longus, and the unbroken line shows its dorsal course after it has been attached to the tibialis anterior. The pronatory and abductory action of the peronaeus longus is clearly indicated, as well as the role of this muscle in preserving the longitudinal arch.

It is not the aim of this article to discuss in detail either the etiology of the muscle imbalance found in this deformity or the corrective methods that can be applied to the deformity. For the infant the conservative methods, started opportunely, are not only the best but are the only ones recommended. When the child reaches twelve or eighteen months of age, however (the "contentious period", so-called by French orthopaedists), the surgeon must decide between conservative treatment and surgery of the soft tissues. Difficulties of decision increase as time passes, and when the child is about four or five years of age, the question is whether surgery must be performed on soft tissues only, on bony structures only, or on both. Each foot constitutes an individual problem, as in each foot the secondary skeletal changes are different.

Two great problems present themselves to the orthopaedist when he has attained the morphological correction of the deformity; how to prevent recurrences and how to obtain a functionally good foot. The answer to both is the same: restoration of the muscle balance. If overcorrection can be fully obtained passively but the child is not able to maintain this correction actively by contracting the peroneal muscles and the extensor digitorum longus, he has a condition of "peroneal insufficiency". This condition may be demonstrated under a number of circumstances; when the foot hangs, when the child is excited or making an effort, when the plantar surface is tickled, and so on. Time must elapse before it is possible to know if the tonus, power, and coordination of the muscles have been restored. If the condition of peroneal insufficiency does not improve spontaneously, surgery is necessary in order to correct the muscle imbalance, the deforming force of the contracted muscles being shifted to the weak points where it is needed. Surgery should only be performed, however, under the following conditions: that bone changes have not yet appeared, that passive overcorrection can be easily attained, and that muscle balance cannot be expected to develop spontaneously.

In club-foot, the tibialis anterior, although weak as an adductor, pulls the metatarsus into adduction, supination, and dorsiflexion, produces supination and adduction of the calcaneus, and raises the first metatarsal bone. Its antagonist, the peronaeus longus, is unable to maintain the balance, and, in the same way, the peronaeus brevis is unable to counteract the tibialis posterior, the strongest adductor of the foot. When shortening of the tibial muscles cannot be overcome by conservative methods, the deformity has to be treated surgically, care being taken at the same time, if necessary, to release the tarsal ligaments of the medial side of the foot and the interosseous subtalar ligament; these latter ligaments not only are shortened but also are hypertrophied. Section of the contracted plantar fascia and lengthening of the abductor and the long flexor of the first toe, when necessary, will take care of the cavus deformity, and lengthening of the tendo achillis will correct an equinus deformity.

If the muscle action is not balanced, recurrence of the deformity, aggravated by fibrosis of the scar tissue, will occur as soon as the passive corrective means are discarded. Several muscle transplantations have been devised in order to prevent this recurrence. The author has tried Garceau's technique several times and has found that very often the tibialis anterior tendon is not long enough to be attached even to the outer border of the

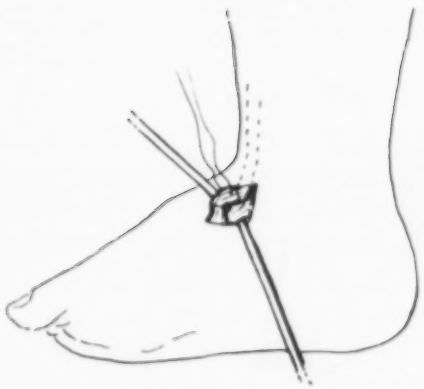

FIG. 2

FIG. 3

Fig. 2: Insertion of an anchoring silk suture and release of the tibialis anterior.

Fig. 3: Surgical approach to the peronaeus longus.

Fig. 4: The peronaeus longus is severed and its proximal end is sutured to the brevis behind the outer malleolus. An anchoring suture is inserted and the distal end of the peronaeus longus is freed.

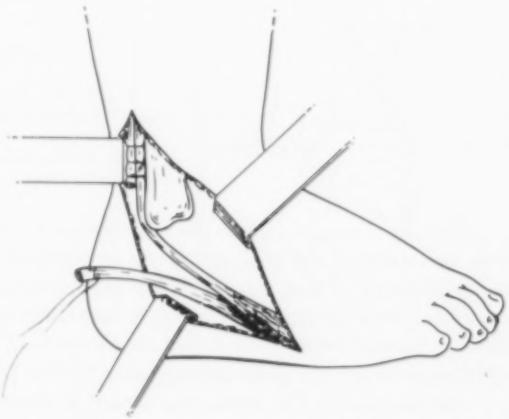

FIG. 4

cuboid. In this case it has to be fixed to the dorsal aspect of the cuboid, which makes it a dorsiflexor with a slight pronatory action and with a negligible abductory action.

If the power of the tibialis anterior is applied over the insertion of the peronaeus brevis, it can act as the strongest pronator of the mid-part of the foot, where the apex of the deformity is placed. In this position, its action cannot be extended to the metatarsus and its action as abductor of the anterior tarsus, although present, is negligible.

If the powerful anterior tibial tendon is transplanted to the peronaeus longus, it acts as a strong pronator and abductor of the metatarsus, and also lowers the first metatarsal bone. Ideally this transplantation will correct the varus deformity and, although it cannot correct the equinus deformity, will provide a balance for the adductory and supinatory force of the triceps surae (Fig. 1).

THERAPEUTIC PROCEDURE

In children under four or five years of age in whom secondary bone changes are not yet suspected, the author tries to obtain maximum correction by means of plaster casts.

If the varus component can be overcorrected by these means but the equinus component cannot, lengthening of the tendo achillis is performed. If, however, the club-foot cannot be hypercorrected by plaster casts, the following procedures are done: in the infant under three years of age, surgical release of the medial and posterior structures is performed and, in the child nearly four or five years old, this release is followed at the same operative session by tibioperoneal tenoplasty. The latter procedure is also performed in all patients in whom several relapses have occurred, for the aim of treatment is to overcorrect the deformity, to prevent recurrences, and to restore the muscle balance before bony changes appear.

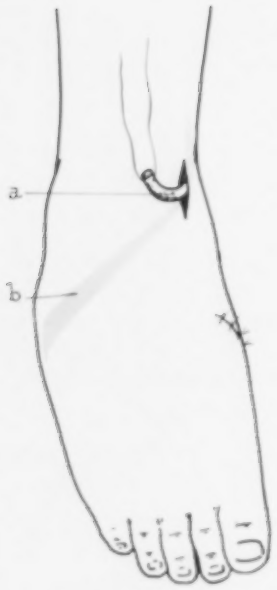

FIG. 5

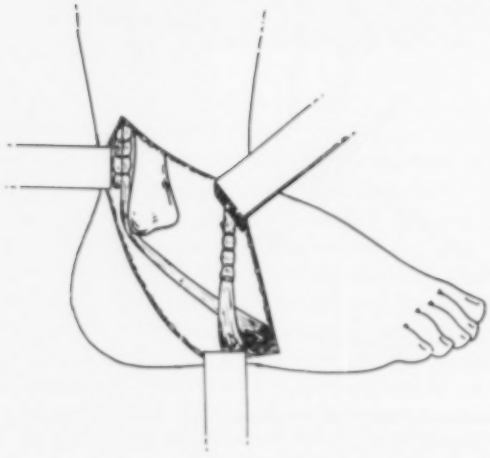

FIG. 6

Fig. 5: The anterior tibial tendon (*a*) is drawn out through a small incision above the transversum ligamentum cruris, and a subcutaneous tunnel is made (*b*).

Fig. 6: The tibialis anterior is sutured to the distal end of the peronaeus longus.

Tendon transplantations have resulted in better and quicker function when they have been performed in children, and correct evaluation of the indications for the operation and the availability of good technical facilities have been two most important factors. Before a surgical decision is made, enough time should be allowed for the peroneal muscles to develop normal tonus, power, and coordination. Clear indications and sufficiently developed tendons are the main prerequisites for the performance of tenoplasty.

Surgical plan: The peronaeus longus is severed above the lateral malleolus and its proximal end is sutured to the peronaeus brevis at this level (Fig. 4). The tibialis anterior is also severed and its end is sutured to the distal end of the peronaeus longus. Thereby, the peronaeus brevis is left intact as the only adequate antagonist of the tibialis posterior.

Indications: This operation is indicated for (1) patients in whom hypercorrection has been attained passively for a sufficiently long time but in whom the action of the peronaei has not been sufficiently improved despite several months of orthopaedic and physiotherapeutic treatment; (2) patients nearly four or five years of age who have had several recurrences of the deformity; and (3) patients in whom overcorrection has not been obtained by conservative methods and in whom secondary bony deformities have not yet developed. In the latter patients the tenoplasty should be preceded at the same operative session by the release of the medial and posterior soft tissues.

Technique

1. A small incision is made over the insertion of the tibialis anterior, and an anchoring suture is passed through the tendon, the end of the tendon having been released (Fig. 2). The end of the silk suture is drawn from the wound, and the wound is then closed.

2. An incision is extended from above and behind the outer part of the malleolus to the tuberosity of the fifth metatarsal bone (Fig. 3), the tendons of the peronaei longus and brevis, being thus demonstrated. The sheath of the former tendon is opened from the level of the posterior aspect of the malleolus to the level of the cuboid-metatarsal joint (Fig. 4), and the contact surfaces of both tendons are scraped and sutured just behind the malleolus. One centimeter below the malleolus an anchoring suture is placed over the

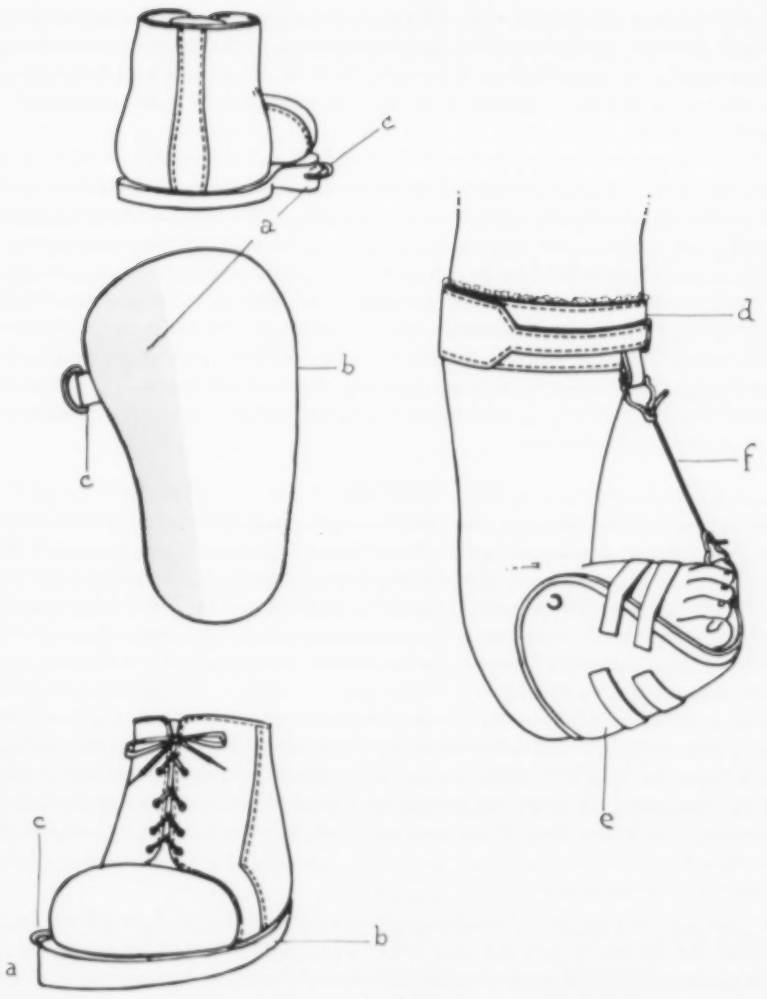

FIG. 7

Corrective shoe and plantar splint for use during the convalescent period: *a*, wedge on the outer side of the sole and heel of the shoe; *b*, abduction of the forepart of the shoe; *c*, ring which is attached to the outer flare of the sole and to which the rubber band is secured; *d*, foam-rubber-lined leather band; *e*, aluminum plantar splint for use at night; and *f*, strong rubber band to be attached to *c*, *d*, and *e*. This device corrects supination, adduction, and equinus deformities.

peronaeus longus tendon, which is then sectioned between this suture and the suture formerly inserted. The sheath of this tendon is carefully reconstructed, the distal end of the tendon being left outside, and a towel clamp is used to close the wound temporarily.

3. A short longitudinal incision is made above the ligamentum transversum cruris, over the anterior tibial tendon, and the latter is drawn out of the wound. A subcutaneous tunnel is then made from this wound to the tuberosity of the fifth metatarsal bone in order that the anterior tibial tendon may be passed to the lateral side of the foot (Fig. 5). The wound above the ankle is sutured.

4. The adduction and supination deformities of the foot are slightly overcorrected, and the distal end of the peronaeus longus is sutured, under moderate tension, to the

tendon of the tibialis anterior (Fig. 6). The wound is closed and a well padded plaster cast is applied to the limb from the toes to the distal portion of the thigh, the knee being maintained in a position of slight flexion. Two weeks later the cast is cut below the knee, and a walking device is attached to the sole of the cast in order that the patient may walk during the next three weeks.

Convalescent care: A corrective shoe without a heel and with lateral wedges on the sole and heel part (Fig. 7, *a*) is prescribed. This shoe maintains the metatarsus in a position of abduction (Fig. 7, *b*). On the outer flare of the sole, at the level of the head of the fifth metatarsal bone, a metal ring is attached (Fig. 7, *c*), and to this ring is secured a rubber band (Fig. 7, *f*), which is fixed by its upper end to the outer side of a sponge-rubber-lined leather band around the leg, below the knee (Fig. 7, *d*). This device will correct the adduction, supination, and equinus deformities without placing any strain on the knee. During the night a plantar splint (Fig. 7, *e*) with the same rubber band is applied, and muscle re-education is carried out several times each day. The rubber band on the shoe is gradually discarded and, later on, the night splint is also discarded, as the transplanted tendon improves in power and function.

RESULTS

The author has noticed that the tibialis anterior functions well in its new position, but that it is difficult to teach the patient to contract this muscle voluntarily. The length of time necessary for some patients to learn to use this muscle automatically contrasts with the quick progress that is made by patients in whom tendons have been transplanted for paralytic club-foot. It seems as if the incoordination of the former patients was due to a developmental defect in the nervous system or to the patient's habit of performing adduction and supination movements of the foot.

Tibioperoneal tenoplasty was performed upon sixteen congenital club feet in thirteen patients; seven of the deformities were on the right side, three were on the left side, and three were bilateral. The first operation in this series was performed on July 1, 1949, and the last on November 24, 1954, the minimum period of follow-up being six months and the maximum, five years. Two of the patients were three years old; four were four years old; two were five; two were six; one was seven; one was nine; and one was twelve. The results were evaluated as follows:

Poor: in one foot the peronaeus longus was so deficient that it could not be used to help correct the deformity and the final result was insufficient passive correction.

Fair: in two feet good passive correction was obtained and there was just sufficient muscle power to maintain this correction.

Good: in five feet the final result was passive correction and slight active hypercorrection.

Excellent: in eight feet a splendid position was passively obtained and there was strong muscle power by means of which the deformity could be overcorrected.

No instances of passive hypercorrection due to overaction of the transplanted tibialis anterior were found; nor were there any instances of adhesion of the tendons that were used in the plastic procedure or of rupture of the sutures. The two feet in which the result was fairly good correction of the metatarsus deformity but moderate supination of the calcaneus belong to a patient with arthrogryposis; this patient could not be treated during the convalescent period. Correction of the supination deformity of the calcaneus was obtained in fourteen feet, and in thirteen of these feet a position of abduction and pronation of the metatarsus was obtained. None of the patients had pain or discomfort after the operation. In five of the sixteen feet, tibioperoneal tenoplasty alone was performed, for in these feet passive hypercorrection could be obtained easily, showing that peroneal insufficiency alone was the cause of the muscular imbalance. In the other eleven feet it was necessary to attain hypercorrection before releasing the soft medial and posterior structure, these procedures being carried out during the same operative session.

Dr. G. de Velasco Polo has reported that six congenital club feet in five patients have been operated upon by him through this method in his private practice; in five of these feet he obtained good results and in one, a poor result, this result being due to defective clinical evaluation. Dr. Funes Hartmann, of San Salvador, El Salvador, has used the author's technique in six operations and the results of these operations have all been successful.

Although the maintenance of good position and the re-education of the tibialis anterior in its new position require considerable time, their importance cannot be over-emphasized. The author recalls once more the words of Steindler: "There is no room in operative orthopedic surgery for any method unless it be applied with the strict understanding that it shall constitute merely an incident in the treatment. Sometimes this incident is most important and sometimes it is a comparatively minor item in the treatment. This is so because orthopedic surgery, conservative or operative, aims at the restoration of form and function and neither of the two can be restored definitely by the single and momentary act of operation."

SUMMARY

In tibioperoneal tenoplasty, the tibialis anterior is transplanted through a subcutaneous tunnel from above the ligamentum transversum to the outer aspect of the dorsum of the foot. In its new location, it is sutured to the distal portion of the peronaeus longus, which has previously been severed above the outer malleolus. The pronatory action of the intact peronaeus brevis is strengthened by the attachment to it of the proximal portion of the severed peronaeus longus. The purpose of this operation is to correct the muscle imbalance and, thereby, to maintain the corrected position of the congenital club-foot and to prevent recurrences.

Sixteen feet were operated upon by the author between July 1, 1949, and November 24, 1954, the following results being obtained: one poor, two fair, five good, and eight excellent. In no case did hypercorrection occur as a result of overaction of the transplanted muscle, and there were no adhesions around the tendons, no failures of sutures, and no instances of postoperative pain in the foot.

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DISCUSSION

Immunological Factors in Homogenous-Bone Transplantation

(Continued from page 328)

3. The reaction by the host appears to be related to the age of the donor, being more marked with grafts of adult bone than with embryonic homografts.

4. The reaction appears to vary in intensity and in predominant cell type. In a few rare cases the homogenous graft seems to survive; more commonly it undergoes aseptic necrosis. In some instances, it is replaced by fibrous connective tissue.

5. The reaction does not appear to be related to known blood-group antigens. The authors have demonstrated this experimentally for the first time, although it has been suspected clinically.

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Dr. Philip D. Wilson, New York, N. Y.: Almost every experienced orthopaedic surgeon agrees that there is a difference between the results of grafting with autogenous bone and with homogenous bone. How great this difference is, is not known, but I believe that when a gap is bridged with an autogenous-bone graft, the chance of the graft's healing is about 10 to 15 per cent better than with the homogenous-bone graft. This difference is thought to be due to the fact that living cells are transplanted with the autogenous graft, whereas the cells of the homogenous graft are dead. Dr. Robert Ray[b] of Seattle has recently announced that he has succeeded, by using tissue-culture technique, in growing cells from refrigerated bone, provided that the bone had been refrigerated gradually and not suddenly. Nevertheless, in his study of the healing of homogenous-bone grafts, he found that the cells contained in the bone apparently die and, on microscopic study, the lacunae are found to be empty. This is not equally true of autogenous-bone grafts, as has been shown by Dr. Herndon and Dr. Chase in some of their early work on joint transplantation in the dog. The plastic surgeons have found that homogenous-skin grafts heal primarily but that they melt and disappear within two or three weeks after grafting. The only time that a graft of homogenous skin will survive is when the donor and recipient are identical twins. This difference in the behavior of skin grafts would seem to indicate the presence of some immunological factor that produces a hostile antigenic response. The present experiments of Dr. Curtiss, Dr. Herndon, and Dr. Chase were intended to shed light on the matter of the incompatible blood factor. They have followed this through very carefully, and the results of their experiments were negative.

As long as fifteen years ago, Dr. Alberto Inclán[a], in reporting his experiments with the use of bone grafts preserved by refrigeration, laid considerable stress on the importance of observing blood types and of using compatible donors as the source of bone grafts. Most of us have completely overlooked his work. As one of the early workers in the use of refrigerated homogenous-bone grafts, I am a little embarrassed when someone asks me about the influence of blood types because very little is known about it.

(Continued on page 376)

Fibrous Dysplasia

Histological Study of Two Unusual Cases *

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Interest in the pathological process termed "fibrous dysplasia of bone" has increased as the lesions have been more generally recognized. The disorder has resisted classification into any of the usual categories of pathology, and, at present, it represents a descriptive entity, or group of entities, of unknown etiology, attributed vaguely to the faulty development of the bone-forming mesenchyme or to some disturbance in the sequences of bone formation. Descriptions of the pathology of the lesions emphasize the wide variety of manifestations in bone ranging from the single, often asymptomatic, lesion to the extreme in which many bones are involved and extraskeletal features become manifest, forming transitional syndromes with some of the aspects of von Recklinghausen's neurofibromatosis or tuberous sclerosis. In the individual lesions, the variety of microscopic pathological features has led to difficulties in the differential diagnosis from many other lesions, all containing fibrous tissue. Thorough studies of the histology of the lesions as they occur in the long bones of the extremities have been rare. Owing to the benign character of the process, specimens from amputations or from autopsies have been available infrequently. This has placed a great limitation on the reconstruction of the general topography of the single lesion, especially since most lesions are large enough so that histological sampling must be done piecemeal. The unusual opportunity to study two small lesions, removed in their entirety and suitable for topographical studies, prompted the publication of this report. The first was a monostotic lesion discovered adventitiously, which demonstrated histological features uncomplicated by superimposed trauma and repair. The second was a lesion which had progressed to pseudarthrosis in a girl who showed precocious puberty and pigmented skin lesions.

Case 1. A boy, nine years and nine months old, underwent a disarticulation of the right hip, performed for a soft-tissue sarcoma of undifferentiated type in the thigh. A fibular lesion, which was asymptomatic, was discovered in the course of a skeletal survey (Fig. 1-A). This child, on physical examination, showed no pigmented areas or other skin lesions. His family history was negative in this respect.

The major nerves, vessels, tendons, and muscles of the amputated extremity were grossly normal, as was the tibia adjacent to the lesion. The fibula, at an area about two inches from the distal end was slightly fusiform and irregular and was of firm consistency. Grossly, in longitudinal section, the lesion was well demarcated, with a thin and discontinuous bony lamina marking its proximal and distal boundaries. The adjoining cortical bone showed marked thinning and slight scalloping laterally, while medially it was thickened and appeared to be cancellous (Fig. 1-B). The periosteum was grossly normal. The lesion was composed of pearl-grey tissue, homogeneous in texture and color, and was of fibrous consistency.

Histologically, the predominant tissue was fibrous with areas of greater and lesser cellularity. Where the cells were abundant, they often assumed a whorled or palisaded arrangement (Figs. 2-A and 2-B). In these areas, the fibrous intercellular material stained for collagen, but some areas showed scant amounts of an amorphous intercellular material. The vascularity of the lesion was not remarkable, and there were no large or abnormal vessels. A smooth transition was seen between the areas of greater and lesser cellularity. The former, in general, were central, and occurred in foci (Fig. 1-B), and, at the periphery of the lesion, the cells tended to be less numerous, with more collagenous and reticular fibers, all of delicate texture. No areas of cartilage or of cyst formation were present. At the periphery of the lesion, a few areas were marked by the production of very im-

* Aided in part by a grant from the Playtex Park Research Institute.

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: The roentgenogram shows the scalloped demarcated irregular lesion of the fibula. It is radiolucent, destructive, and has eroded the cortex. The longitudinal section (× 3) comprises most of the lesion. The upper border is bounded by a thin discontinuous lamina of bone. The thin lateral cortex contrasts with the irregular cancellous structure of the medial cortical layer. Note the differences in cellularity of the various portions and the sparse areas of bone metaplasia.

mature bone matrix, and all stages of bone production could be seen from thin intercellular bands or nodules of osteoid to immature trabeculated bone of fibrous type (Fig. 3-B). No mature-bone formation within the lesion was evident. In the transverse sections, the areas where the lesion adjoined mature bone were of particular interest. In some of these areas (Fig. 3-A), the mature bone trabeculae were crescentic in cross section with the concave side filled by a streamer-like projection of cells and fibers from the main mass of the lesion. These projections of tissue were usually flanked by normal fat. The convex border of the bone trabeculae was similarly lined with normal fatty marrow. In a few areas in which cellular portions of the lesion abutted mature bone, osteoclasts were numerous, but, in most areas of erosive resorption, the cells adjacent to the trabecula resembled osteoblasts, although they were oriented haphazardly. In these areas the fibers of the bone were continuous with those of the lesion. The areas in which the lesion adjoined mature bone were marked by a gradual transition to a looser connective tissue identical with the fibrous marrow seen in lesions in which resorptive processes predominate (for example, in renal osteitis fibrosa and hyperparathyroidism). This type of tissue occurred not only at the periphery of the lesion but also in the interstices of the trabeculae of the cortex and in Volkmann's canals leading to the periosteum (Fig. 4).

Many areas of normal cortex, although much more cancellous than usual, were the

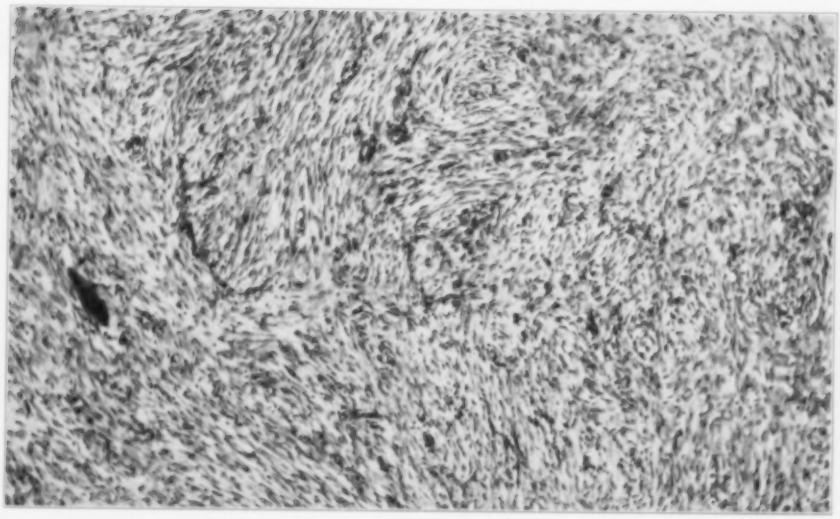

FIG. 2-A

The predominant tissue of the lesion. The fibrous elements are delicate and only moderately abundant. The cells are arranged in palisades or whorls sometimes resembling herringbone patterns.

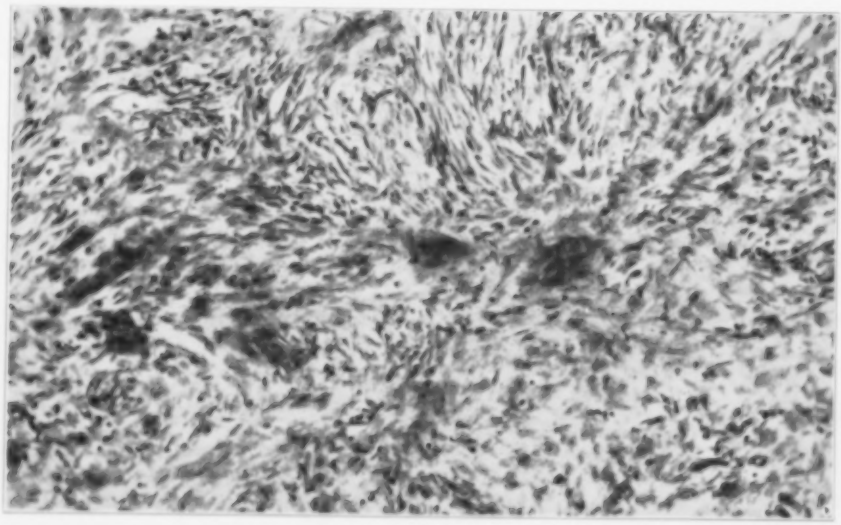

FIG. 2-B

A few giant cells among the whorls. The cells of the lesions are somewhat plumper and less spindle-shaped than fibroblasts. The giant cells resemble osteoclasts.

sites of deposition of bone, rather than of resorption. Strangely enough, the area in which the cortex was reduced to a thin lamina was that showing most active deposition (Figs. 5-A and 5-B).

The periosteum, where active, showed resorption of bone rather than deposition. The resorptive areas consisted of loose fibrous tissue occupying scalloped eroded lacunae, with an osteoclast visible only rarely. The fibers of the bone surface were continuous with those of the fibrous tissue overlying it.

The distal and proximal limits of the lesion were of similar configuration. An interval

FIG. 3-A

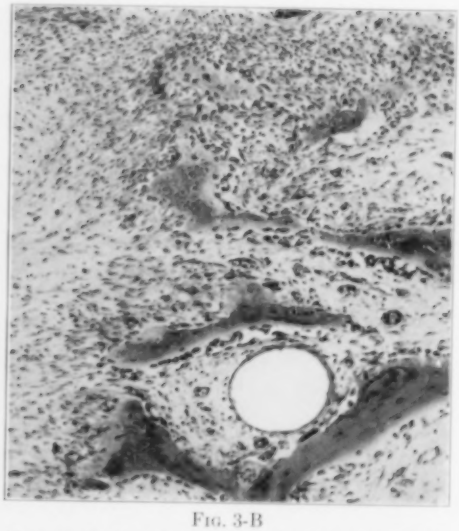

FIG. 3-B

Fig. 3-A: Cross section showing mature trabeculae of bone eroded by streaming bands of tissue from the lesion (right). Note the lack of involvement or infiltration of the fat.

Fig. 3-B: Area of metaplasia of the lesion into immature bone. Osteoid borders are visible. Trabeculation is rudimentary. The transition of cell shapes from those of fibroblast type to osteoblasts may be noted from left to right, with characteristic streaming formations.

of two centimeters of normal fatty marrow separated the lesion from the epiphyseal cartilage, which was normal. The boundaries of the lesion were abrupt and consisted of thin, discontinuous laminae of mature bone (Fig. 6). These limiting laminae of bone showed varying degrees of maturity of structure and, facing the lesion, were undergoing resorption, although several areas displayed wide osteoid seams.

One subperiosteal area was seen in which the cortex was completely resorbed and the fibrous layer of the periosteum dipped into the lesion (Figs. 7-A and 7-B). The denser fibers of collagen from the periosteum were easily distinguishable from the more delicate stroma of the lesion. They were much more abundant than those in the adjoining areas

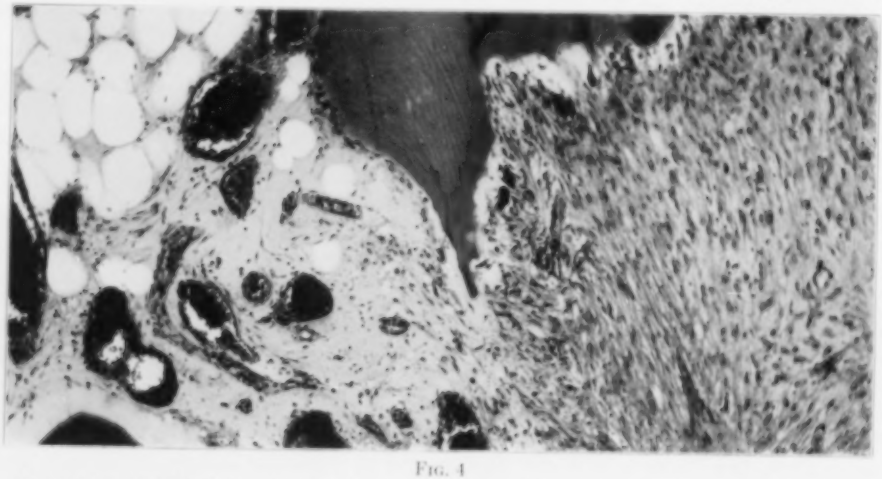

FIG. 4

Lateral border of the lesion. An eroded trabecula is seen, whose fibers are continuous into the lesion. At the left are engorged vessels in a loose connective-tissue marrow which merges into the lesion without demarcation.

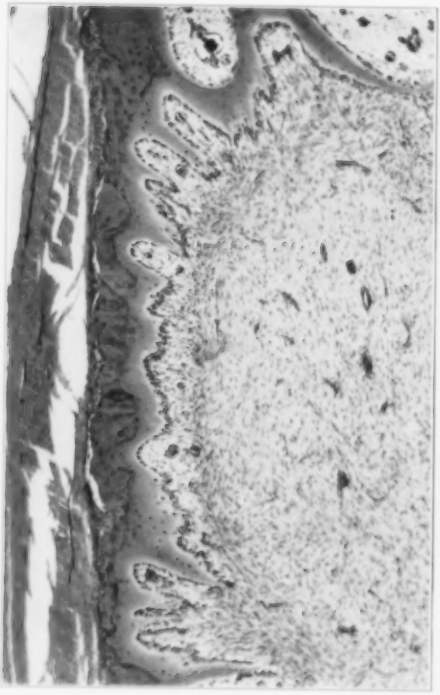

FIG. 5-A

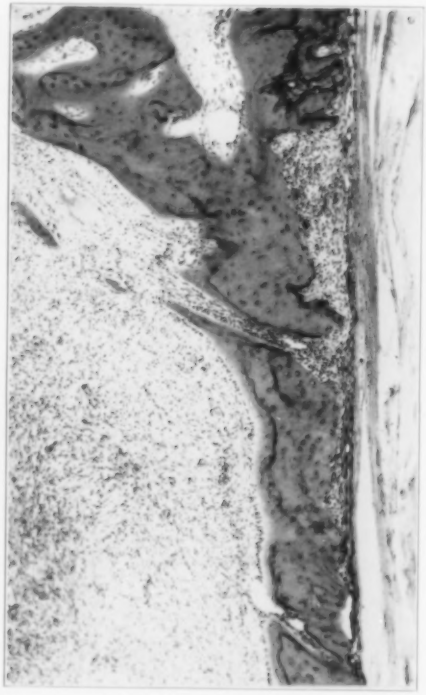

FIG. 5-B

Two sections of thin cortex showing predominantly osteoblastic formation despite the thinness of the cortical layer and the transition of the cells of the lesion into osteoblasts. At the right, the periosteum shows tissue similar to that in the center of the lesion with erosion of the bone and continuity through a Volkmann canal.

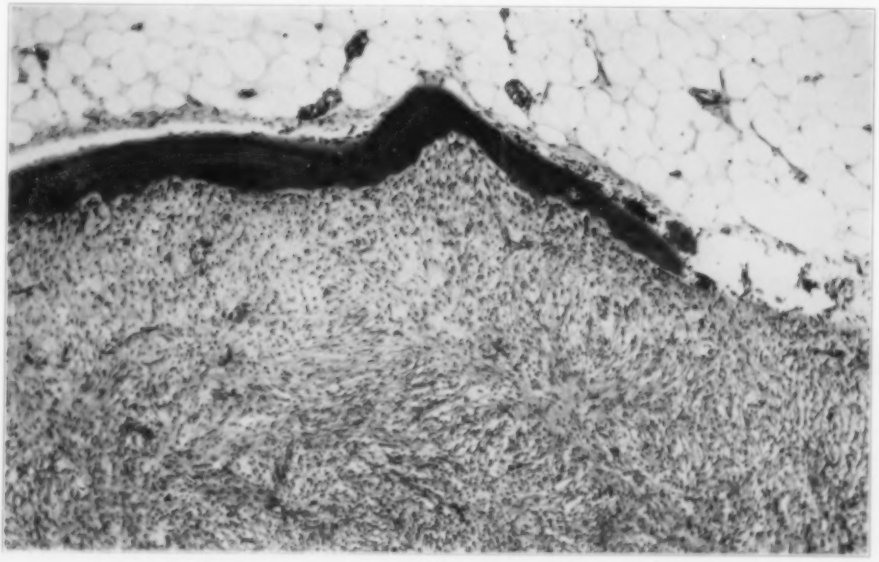

FIG. 6

The upper border of lesion. Note discontinuous thin bony lamina manifesting resorptive sequences on its lower aspect and deposition of bone on its upper aspect. The fat is not infiltrated and the cells of the lesion are sharply demarcated from it.

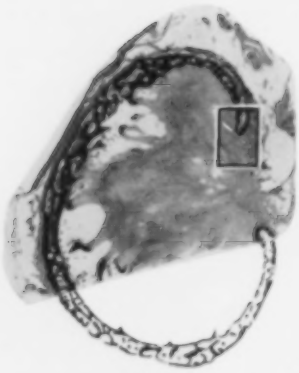

FIG. 7-A

On the left (Fig. 7-A) is a reconstruction of a cross section to show complete resorption of the cortex laterally. The clear areas medially are adult fat. A few clefts are seen and a few areas of osseous metaplasia. The lower part was removed for longitudinal sections. The photomicrograph (Fig. 7-B) is an enlargement of the inset to show the infiltration of periosteal coarse fibers of connective tissue into the lesion.

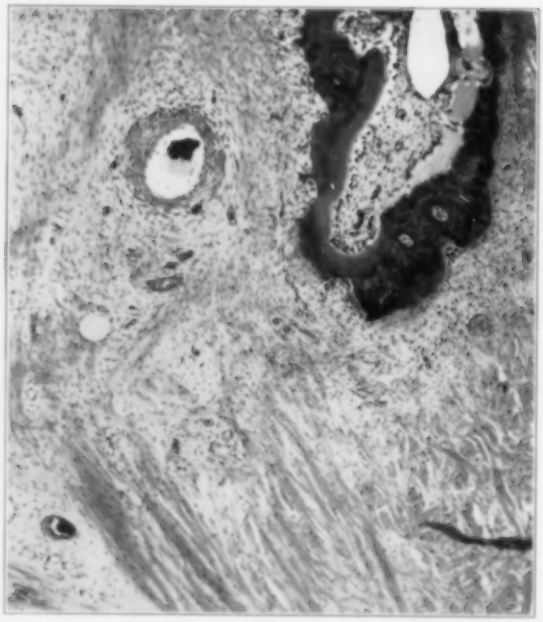

FIG. 7-B

where a thin shell of cortex remained; they assumed a herringbone or interlacing pattern reminiscent of some fibromata. When traced into the lesion, the collagenous fibers from the periosteum became separated and were diffusely incorporated within the lesion.

The cells which predominated in the lesion were fibroblasts and reticular cells. En-

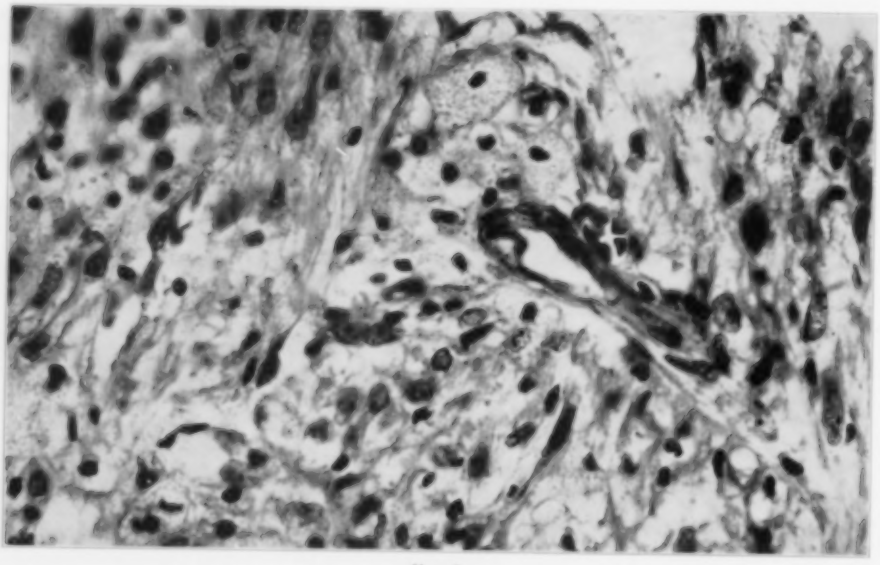

FIG. 8

Area showing foam cells in clusters near a blood vessel. The cells at the extreme right have large oval nuclei and are in bands and are probably endothelial. Many of these are seen in cross section throughout the section.

FIG. 9-A

Roentgenogram (1951) and longitudinal section of pseudarthrosis in Case 2. The cystic areas at the pseudarthrosis are easily visible. The tibia seems to be uninvolved. The photomicrograph (Fig. 9-B) shows the coarse fibrous tissue composing most of the lesion. At the upper right, periosteal resorption of the cortex is seen. Reactive bone is abundant as internal callus. The lower fragment is capped by fibrocartilage.

FIG. 9-B

dothelial cells, often in channel-like bands, also were seen (Fig. 8). Nearly all areas of the lesion contained reticulum fibers. Degenerative changes were especially numerous and diverse in the cells of endothelial type, with no inflammatory cells present.

In several areas close to whorls or palisades, multinucleated cells were found in scattered groups. The numbers of nuclei ranged between five and twenty-five, and the configuration and arrangement of the nuclei were identical with those of osteoclasts. Foam cells, which stained well with Scharlach R, were found in large numbers and were often in sheets in various portions of the lesion, but no relationship could be established between the location of these cells and the areas in which degenerative changes in nuclei were seen. While scattered small foci of lymphocytes could be found in the lesion, these too bore no intimate relationship to the foam cells. An attempt was made to determine whether transitions occurred between normal fat cells and the foam cells. None were demonstrable. There were no areas of fat necrosis, or indeed, of necrosis of any significant number of cells.

CASE 2. A girl first complained of pain in the left ankle in 1950 when she was seven years old. This had followed minimum trauma, and the physician consulted had diagnosed an old fracture of the fibula. The pain was not severe, and no treatment was instituted. At about the same time, she began to show precocious enlargement of the breasts and pubic hair, which were her principal presenting complaints. The area of fracture occasionally was the site of discomfort, at which times she had an antalgic limp, but there was no swelling, mass, or deformity. The family history and the patient's past history presented no data which were considered pertinent. The initial physical examination in 1951 disclosed a well developed obese adolescent white girl. She was in the upper 3 per cent of the population on an age-height scale. Her intelligence quotient was 85. She showed many large and small pigmented *café-au-lait* areas on the trunk, back, and extremities. No subcutaneous nodules were present. Breast enlargement was advanced, and pubic and axillary hair were abundant and coarse. The external genitalia were of adult female configuration. The

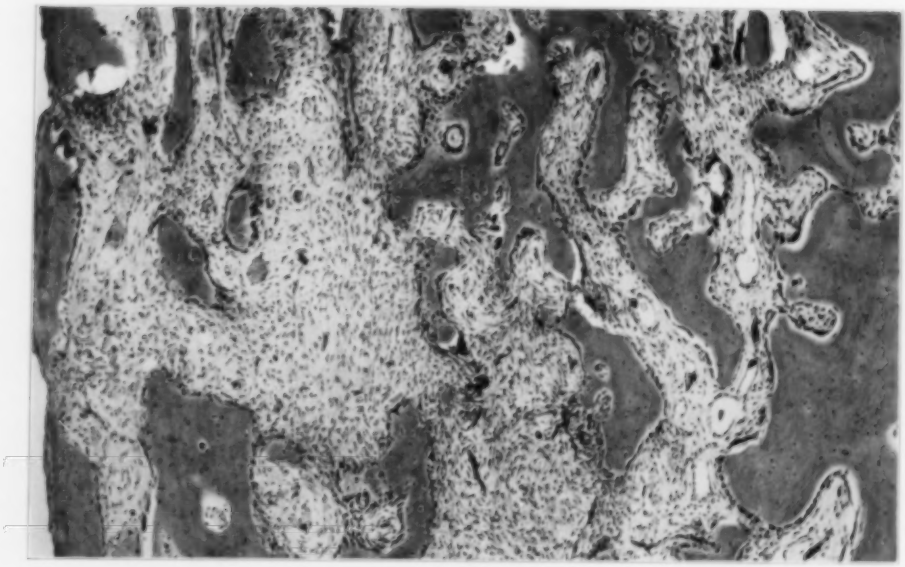

FIG. 10

Section of tibia to show contrast with histological picture of fibular lesion. On the left is the periosteal border, on the right the remains of normal cortex. Note the concomitant active resorption and deposition. No coarse fibrous interlacing bundles are present. Osseous metaplasia of immature trabeculae and delicate fibrous structure between them compose the bulk of the lesion.

thoracic and abdominal viscera were normal, and no neurological abnormalities were found. The left lower extremity showed atrophy of one centimeter of her calf and thigh. Apart from slight valgus deformity of the left heel and a minimally depressed area in the lower third of the fibula, no deformities, tenderness, or masses were noted and no functional disability was demonstrable, although the distal third of the fibula was freely movable. The laboratory examinations considered pertinent were: serum calcium, 9.2 milligrams per 100 cubic centimeters; serum phosphorus, 5 milligrams per 100 cubic centimeters; alkaline phosphatase, 12.6 Bodansky units; serum protein, 6.9 grams per 100 cubic centimeters; and urinary 17-ketosteroids, 2.24 milligrams in twenty-four hours. A vaginal smear showed marked estrogen effect. The bone age was twelve years as against chronological age of eight years. Roentgenograms of the fibula (Fig. 9-A) showed pseudarthrosis in the lower third of the fibula, with cystic changes in the area, and atrophy and attenuation of the shaft of the distal fragment. A skeletal survey showed no other bone lesions, but calcification of both choroid plexuses and of the pineal gland was present.

The patient was observed for a period of one year, during which time her left ankle became intermittently more painful and the valgus deformity of the heel increased slightly. As seen by roentgenogram, the pseudarthrosis did not change appreciably. The menarche occurred and the bone age advanced to thirteen years. In October 1952, a block excision of the lesion of the fibula was performed and a frozen homogenous-bone graft of a segment of metatarsal bone was inserted. Fixation was by means of an intramedullary Kirschner wire, inserted retrograde. The area of pseudarthrosis was fibrous and was confluent with the septa of the region. It did not involve the adjacent tibia. On the medial surface of the upper fragment just above the pseudarthrosis there was an irregular bony nodule. The upper fragment was diffusely enlarged at its pseudo-articulation, while the lower was thinner than the normal. A small irregular medullary cavity was present in both fragments down to but not including the area adjoining the pseudarthrosis.

The specimen removed was a segment of fibula about five centimeters long which included a portion containing the pseudarthrosis and the adjoining soft tissue. The soft tissues were not detached from either fragment, and the area of pseudarthrosis was also left intact. At its periphery, it merged into the fibrous tissue of the area without definite demarcation; no periosteal layer could be distinguished from the dense fibrous tissue adjoining the pseudarthrosis.

Postoperatively, plaster casts were used for a long period because of roentgenographic evidence of delayed healing. A scalloped defect in the tibia developed adjacent to the graft. The urinary 17-ketosteroids rose to 5.1 milligrams in twenty-four hours. In May 1953, a second operation was performed and consisted in excision of a portion of the tibial lesion and a reinforcement of the fibular graft at its distal portion with autogenous iliac bone. The graft was found to have united at its proximal, but not at its distal, extremity, where fibrous union was demonstrated. The tibial lesion at operation was found to be more extensive than

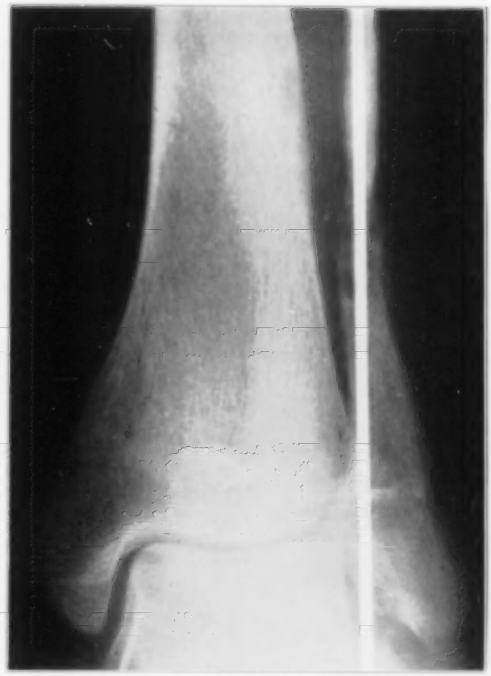

FIG. 11-A

FIG. 11-B

Roentgenograms (November 1952 and March 1954) showing the cystic changes in the fibula following the grafting procedure and the progressive resorption and healing of the grafted area. Note the tibial lesion adjoining the pseudarthrosis. It is irregular, diffuse, and erosive in the roentgenogram on the left (Fig. 11-A) while it is denser and smoother after the biopsy (Fig. 11-B).

was indicated by roentgenograms. It extended along an expanse of about four centimeters. The periosteum overlying it was thin and was not involved by extension from the fibular lesion. The tibial surface was roughened and reddened. A block about two by one centimeters was excised.

It consisted grossly of a strip of bone somewhat softer than cortical bone with intact thin periosteum. This was well demarcated from the surrounding soft tissue. The cut edge of the specimen showed an area of cancellous bone underlying the periosteum to a depth of 0.5 centimeters and merging irregularly with normal appearing cortex beneath (Fig. 10)

The course of the condition to July 1955 was one of slow but definite bony union. Several small cystic areas (Figs. 11-A and 11-B) developed in the fibular fragments above and below the graft site and then disappeared. The tibial lesion did not change significantly.

Microscopically, the fibular specimen was composed of an irregular band of fibrous pseudarthrosis, 0.4 centimeter thick, intervening between osseous segments whose periosteum was continuous with it. The periosteum of the specimen was greatly thickened except on the proximal portion of the proximal fragment, where it was normal. Thickening of the periosteum began near the pseudarthrosis and along the more distal parts of the specimen. In the thickened part, no demarcation from the surrounding fibrous tissue was evident, and the principal configuration was one of the interlacing bands of coarse fibers often in herringbone patterns (Figs. 12-A and 12-B). The cambial layer showed many discontinuous areas of bone resorption, often characterized by osteoclasts and extensive scalloping of the cortex. In some areas of erosion of the cortex, streamer-like bands of fibrous tissue seemed to project from the periosteum into the cortex. These bands contained not only coarse collagen fibers which seemed continuous with those of the bone, but also areas of metaplasia into immature bone and scattered giant cells (Figs. 12-A and 12-B). These streamer bands occurred principally at some distance from the pseudarthrosis. Thin

lamellae of new bone under the periosteum were present, but trabecular deposits resembling callus were absent. The fibrous tissue composing the pseudarthrosis was continuous with the periosteum. The predominant picture was one of coarse bands of fibers with numerous fibroblasts between them. Small scattered areas of osseous metaplasia occurred in immature, non-trabeculated patterns. No area of metaplasia into cartilage was found

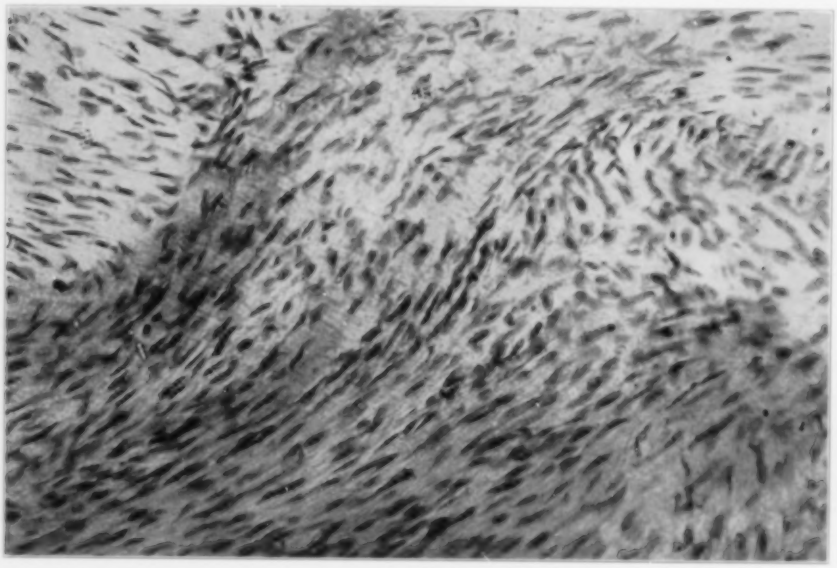

FIG. 12-A

Characteristic tissue composing most of the lesion. Predominant are fibroblasts, coarse fibrous tissue, and interlacing bundles.

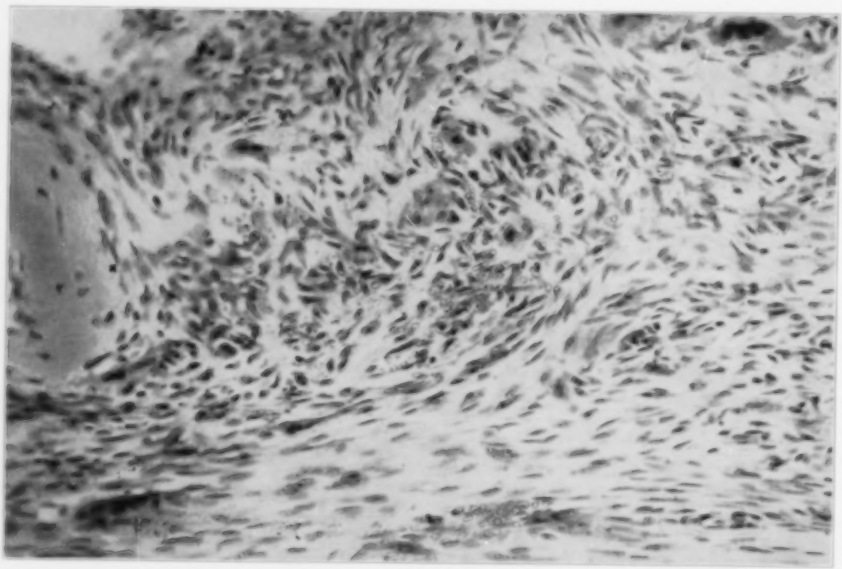

FIG. 12-B

Cellular area from one of a few infrequent foci. Osseous metaplasia on the left, a few giant cells, and a tendency to whorl formation are shown.

except on the distal osseous fragment. Several areas were seen where cells with larger and plumper nuclei abounded, and these areas of increased cellularity were marked by fewer and more delicate fibers. These occurred in the pseudarthrosis in scattered foci; they could also be found in the interstices of the bone nearby and subperiosteally. They tended to assume formations as bands or masses rather than whorls and palisades. The latter formations were present in the interlacing patterns of the pseudarthrosis, but never to the degree seen in neurofibromata. Verocay's bodies were not seen. Whorls were noted principally in relation to blood vessels. Neurofibrils were only rarely seen in the periosteal area in small nerves. Occasionally a cleft was seen lined by cells resembling a synovial layer. These clefts did not extend across the pseudarthrosis, but were discontinuous and were adjacent to the distal osseous fragment. At the tip of this tapering segment of bone, there was an extensive zone of metaplasia of fibrous tissue to cartilage. The medullary portions of both the distal and proximal fragments showed a narrow segment of active remodeling processes consisting of areas of bone deposition and resorption at the pseudarthrosis; beyond these, there was normal fatty marrow and occasional cancellous trabeculae.

The tibial specimen, studied microscopically, showed periosteum of normal thickness and structure. The lesion appeared as a scalloped area underlying the periosteum and encroaching on the cortical bone to a depth of approximately 0.5 centimeter. This area was saucer-shaped and contained a tissue predominantly fibrous with many areas of metaplastic bone within it. The tissue was highly cellular and the fibers were rather sparse and delicate. This tissue filled the Haversian canals immediately adjacent to the lesion and dipped into the erosive lacunae of the surface wherever they occurred. Although some of the cells assumed the appearance of whorls and palisades, no bands of interlacing fibers, as seen in the fibular lesion, were present. The metaplastic bone was more mature than in the specimens described and often had a trabecular pattern. It showed active resorption and deposition, with the former predominating. Osteoclasts were numerous. No neurofibrils or foam cells were seen. Beneath the bone immediately adjoining the lesion, normal fatty marrow was evident.

DISCUSSION

The pathological features of fibrous dysplasia have been described at length in articles by Jaffe and Lichtenstein[3,4,5] and in a recent review by Pritchard, to which the reader is referred for a general consideration of the disease. The discussion of the two cases reported will be directed to several points of controversy concerned with the histology and nature of the lesions to which the present material is relevant.

It is agreed that the formation of atypical patterns of fibrous tissue constitutes the cardinal feature of the lesions. Formation of immature bone also is commonly seen, although in the two cases under consideration, it was not overly conspicuous. The principal disturbance in the tissues is one of organization, and, while this disturbed organization may ultimately depend on metabolic factors localized in cells of the lesion, morphologically, at least, the cells do not vary from the normal constituent cells of the connective tissues. A transformation of less differentiated connective-tissue cells into osteoblasts occurs in the process of normal formation of bone; and, in the lesions of fibrous dysplasia, this transformation also is quite evident. What is pathological is the pattern of trabeculation of the new bone, that is, the retention of immature callus-like formations. The same concept of an organizational defect may be applied to the fibrous tissue produced. Certainly no functional arrangement of connective-tissue fibers can be made out, and each fiber is more delicate than those predominating in ordinary fibrous tissue. Pritchard offers the suggestion that the whorled arrangement of the cells and fibers is related to the formation of bone trabeculae; and, in the specimen from Case 1 (Fig. 3-A), the streamer arrangement seems to be in accord with this view. Some portions of this specimen contained non-

fibrous, poorly staining intercellular material, the neighboring cells showing no degenerative changes. Oedema therefore being unlikely, one is tempted to speculate that the material present might be a material analogous to that described in scurvy [7], in which intercellular substances do not achieve their proper maturity.

Passing from a consideration of the organization of the pathological tissue and its intercellular matrix to its cytology, one of the two lesions described showed, besides the usual elements, large collections of foam cells. These apparently were derived from reticular cells and were found in clusters and sheets. It appears unlikely that the foam cells are incidental reactive elements of the lesion; the suggestion was entertained that they represented stages in the formation of fat. This, too, was considered unlikely, since transitional forms to adult fat cells were not present. The most plausible, but still rather unsatisfactory, explanation of their presence was that they represented histiocytes with disturbed metabolism and resultant accumulation in the foamy cytoplasm of either lipid or lipoprotein.

The specimen from Case 1 showed by the cellular activity at its edges that it was an enlarging lesion, yet the manner of its enlargement was obscure. It did not expand the cortex. In one area the original cortical layer had been resorbed, but in this area the fibrous tissue of the lesion did not bulge as if released from the confinement of a bony cage. In fact, the reverse situation was seen, and the periosteal elements were depressed into the cortical gap. In the presence of increased cellularity of the area, one may infer that, while the cells were dividing, their production of intercellular substances was decreased from the normal.

The periosteal areas of dysplasia offer indications that at least part of the enlargement of the lesion was due to the incorporation of the local cells into the process rather than by the expanding pressure of cellular growth. Moreover, the cellularity at the periphery of the lesion was less than that at the center. Confirmatory evidence may be adduced from the appearance of the limits of the lesion proximally and distally, where a thin discontinuous bony lamina was present, representing, according to this line of thought, the closest approach of the differentiation of the tissue to normal bone. Since areas of the periosteum showed that resorption of cortical bone was actively occurring at the level of the lesion, it becomes reasonable to suppose that the enlargement of the lesion occurred by dedifferentiation of the tissue elements of the periosteum, as well as of the bone, to less differentiated types.

Two features of the histology of the lesion in Case 2 merit comment. The first is the marked difference between the pattern of the fibular lesion and that of Case 1, and the second is the discrepancy in the patterns of the adjoining fibular and tibial lesions in the same patient. The fibular lesion of Case 2 was characterized by a predominance of coarse fibrous tissue, in which bands of fibers often interlaced. This type of tissue was not found in Case 1, and can be interpreted as arising from a reparative response to the fracture and subsequent pseudarthrosis. Small areas of looser atypical fibrous tissue were found in both cases, and it is felt that these represented in Case 2 the predominant tissue prior to fracture. This tissue, characteristic of fibrous dysplasia, occurred not only within the diaphysis but also subperiosteally. This is in accord with a concept of a segmental disturbance. The occurrence of a tibial lesion at the same level is additional evidence for this theory.

The tibial lesion, a subperiosteal area filled with the characteristic tissue of fibrous dysplasia and not continuous with the fibrous tissue of the pseudarthrosis, is thought to represent a lesion uncomplicated by trauma or by reparative processes. We may surmise, therefore, that the fibular lesion of Case 2 underwent a sequence of repair which nearly obliterated the original lesion. When considering the adequacy of the repair process, it will be recalled that following both grafting procedures bone elaboration was slow and was accompanied by roentgenographic evidence of cystic areas of resorption of the grafts; nevertheless, it is evident that bony union occurred within the area of dysplasia.

Comparison of these two cases with the other instances of fibrous dysplasia seen at

this Hospital or reported in the literature reveals that a wide variety of histological patterns can be found but that, in lesions uncomplicated by reparative processes, the loose fibrous, whorled pattern usually composes the major part of the lesion. The amount of immature-bone formation, and the degree of immaturity may vary within wide limits; in some lesions, for example, that in Case 1, very little new bone may be seen, while other specimens, for example, that from the tibial specimen of Case 2, may show significant osteogenesis. The other potentialities of the lesion may vary similarly, so that foam cells, endothelial cells, synovial clefts, cysts, cartilaginous nodules, and giant cells may be present in varying profusion and combinations in different portions of the same lesion. It is not known whether different lesions in the same patient will show similar histological variations, but the discrepancies between the fibular and tibial lesions in Case 2 suggest this possibility and further emphasize the probability that local factors are of greater import than systemic factors in the development of the bone lesions.

In the literature, much attention has been given to the development of lesions, while only occasional references are made to their ultimate fate. The predominant view is that the lesions become quiescent in time. In polyostotic forms, a period of hyperactivity in the lesions may occur during puberty, which was true in Case 2. However, the possibility that lesions may spontaneously recede or show repair has not received wide notice, and Case 2 deserves emphasis in that respect.

It also may be of interest to note the identical localization of the two lesions here reported and the similarity, both in respect to histology and area of bone affected, between the fibular lesion of Case 2 and that of the case reported by Green and Rudo. In the latter case, however, the diagnosis of neurofibromatosis was well supported by the finding of tumor nodules on peripheral nerves, which were absent in the case here presented. For further discussion of this problem, the reader is referred to the paper of Aegerter. The similarity in histology may be attributed to the predominance in each case of reparative elements which may have replaced much of the tissue of the original lesion.

SUMMARY

Two cases of fibrous dysplasia of bone have been reported. The first represents a fibular lesion discovered incidentally, which illustrates varied histological patterns uncomplicated by fracture and repair. The manner of enlargement of the lesion, the participation of the periosteum, and other histological data have been presented. The second case, that in a girl showing precocious puberty and pigmented skin lesions, is a fibular lesion which progressed to pseudarthrosis and an adjoining but separate superficial tibial lesion. In this case, the differences in the histology of the two lesions and the effects of repair in obliterating the original histological appearance are discussed.

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Sternomastoid Tumor in Identical Twins

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Little is known about the genesis of sternomastoid tumors despite experimental and clinical studies. Suggestions as to the cause of these tumors include intra-uterine positioning and pressure, the trauma of birth, blood-vessel occlusion, heredity, infection, and neurogenic malformation. Middleton laid the basis of contemporary thought by his experiments; he showed that only by causing venous occlusion could he produce the pathological changes which are typical of sternomastoid tumor. He felt that congenital torticollis is the end result of the occurrence of venous occlusion during birth. Chandler and Altenberg felt that the intra-uterine position of the foetus, trauma at birth, and a pre-existing change in the involved muscle are etiological factors. On the basis of the anatomical dissections they had done, they felt that venous anastomoses, both within and without

FIG. 1

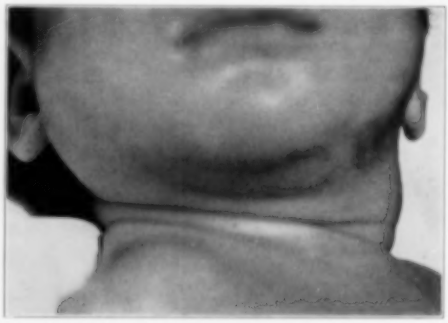

FIG. 2

Fig. 1: In Twin A the sternomastoid tumor is on the right.
Fig. 2: In Twin B the sternomastoid tumor is on the left.

the sternocleidomastoid muscle, are numerous and that the occlusion of one or more veins could not produce the pathological picture found in sternomastoid tumor. They called this tumor a "fibroma".

The possibility that this disorder may have a congenital basis, that it may be due to some defect in the development of the foetus, has only occasionally been suggested. In their study of 101 cases, Chandler and Altenberg found that the incidence of associated abnormalities which could be detected by clinical methods was low; Erb's palsy was an associated condition in three cases, hypertrophic pyloric stenosis in three cases, and a congenital short arm in one case. Reye reported that in four autopsies of infants under six months of age sternomastoid tumors were found in association with other congenital anomalies.

Careful analyses of the incidence of this condition in more than one member of a family have been made. In their series of 101 cases, Chandler and Altenberg noted that the mothers of two patients had untreated torticollis and that the brother of one other patient had a fibrous cord that replaced the sternocleidomastoid muscle on one side. Von Lackum reported that in a family of four children three had congenital torticollis, and Stevens described the presence of congenital torticollis in identical twins twelve years of

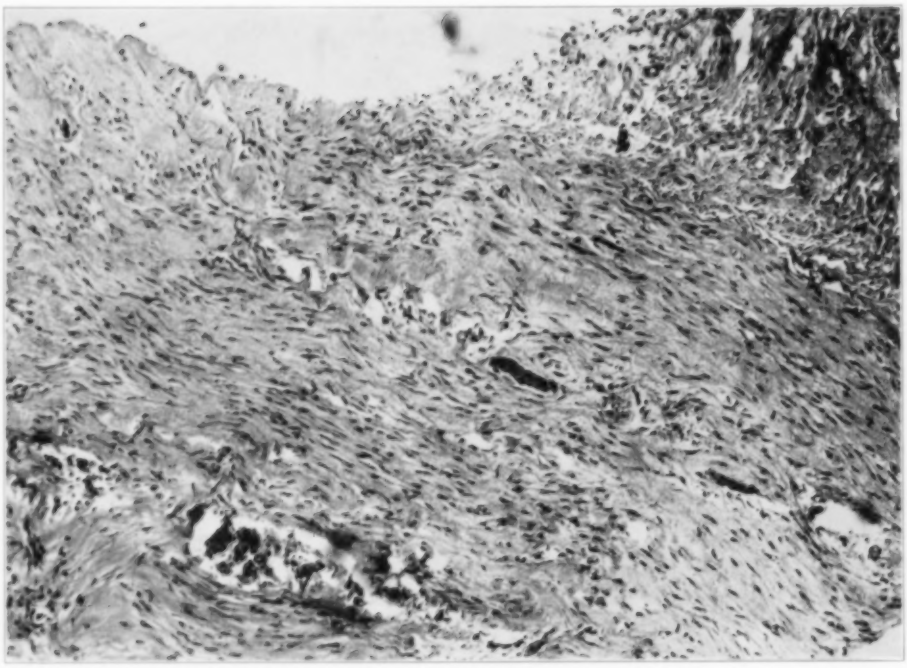

FIG. 3

Photomicrograph (× 107) of the tissue removed from the sternomastoid tumor of Twin B. The degenerating muscle fibers are surrounded by dense fibrous tissue.

age. In the latter cases, there was no known history of difficulty during labor. The twins each had torticollis with a fibrotic sternocleidomastoid on the right, and there was a right facial hemi-atrophy and an early scoliosis of the lower cervical and the upper thoracic spine. The physical defects in these twins were the same.

The following report describes the occurrence in mirror-image of sternomastoid tumors in identical twins. This case suggests that, possibly, the sternomastoid tumor is congenital in origin.

CASE REPORT

The mother of the twins, a white primipara, twenty-three years old, was admitted to the Albany Hospital shortly after the onset of labor pains. Roentgenograms revealed the presence of the twins, one in the breech and the other in the transverse position. No deformity was known to exist in any other member of the family, and no deformity was apparent in the skeletal structure of the twins. The first twin (A) was delivered without difficulty in the breech presentation, but the second twin (B) required version from the transverse position to the breech position. There was no apparent difficulty in delivering the head of either twin.

Examination at birth by a pediatrician revealed no discoloration or deformity. Fourteen days following birth, however, when the twins were examined prior to discharge, a mass was noted in the right sternocleidomastoid of twin A (Fig. 1) and a similar mass was noted in the left sternocleidomastoid of twin B (Fig. 2). These masses were identical in size and consistency, and a diagnosis of sternomastoid tumor was made for each. Aspiration biopsy was performed in each twin on the fifteenth day following birth. The microscopic appearance of the biopsied material (Figs. 3 and 4) was characteristic of sternomastoid tumor; the section revealed a far advanced stage of degeneration in the muscle fibers, as well as the replacement of these fibers by fibrous tissue. Treatment consisted in passive stretching. The result was excellent and no persistent deformity was present two years following birth.

DISCUSSION

The occurrence of a deformity in identical twins, either on the same side or in mirror-

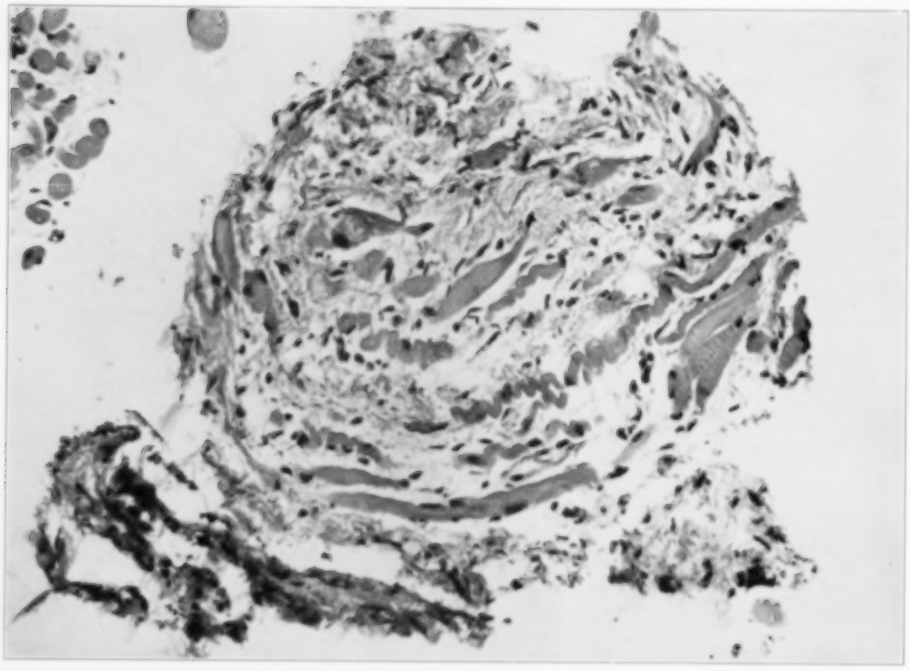

FIG. 4

Photomicrograph (× 260) of the tissue removed from the sternomastoid tumor of Twin A. The higher magnification shows all stages of muscle degeneration.

image, suggests that the deformity is congenital; the possibility of identical traumata or venous occlusion is mathematically remote. Kambara reported several instances of congenital dislocation of the hip in identical twins. The authors' cases and the cases in identical twins reported by Stevens suggests the etiological possibility that sternomastoid tumor is a basic congenital abnormality.

NOTE: Acknowledgment is made to Jack Spitalny, M.D., Department of Pediatrics, Albany Medical College.

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Fractures of the Triquetrum

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Fractures of the triquetrum are only occasionally seen, but they are disabling, and their recognition is essential for adequate treatment. An excellent paper on this subject by Bonnin and Greening appeared in 1944 in which they analyzed sixty cases. Little has been written on this subject since then. This article will review the types of fracture with their roentgenographic features and will touch upon their clinical course and management.

FREQUENCY

The present study is based on forty-six triquetral fractures found over a four-year period in a busy out-patient clinic. During this time over 2,500 roentgenographic examinations of the wrist were made, mostly of active adult males, which showed that fractures of the triquetrum occur infrequently. While triquetral fractures do form the second most common group of carpal fractures, they are nevertheless uncommon as compared with navicular fractures; for example, Kellam and McGoey report 145 navicular fractures and eleven triquetral fractures. In a general hospital of 350 beds, the authors have seen fewer than one triquetral fracture a year. Fractures of the other carpal bones are even less frequent.

MODE OF INJURY

Bonnin and Greening describe in detail the mechanics of triquetral fractures. We are unable to ascertain the exact mechanism underlying these fractures in as much detail. A number of our patients could not recall the precise manner in which the accident occurred and some of the histories may have been biased because of compensation and liability claims. In most of our cases, fractures of the triquetrum resulted from one of the following causes:

1. Injuries resulting from falls on the hand with forcible palmar flexion or, more frequently, with violent dorsiflexion of the wrist;

2. Injuries to the dorsum of the carpus from direct blows;

3. Injuries associated with sudden resistance against twisting motions of the wrist such as may occur in lifting heavy sacks of mail.

SYMPTOMS AND SIGNS

As is to be expected fracture of the triquetrum is followed by pain, swelling, tenderness, and restricted movement of the wrist. These findings may be slight or pronounced. They may be localized over the triquetrum or more generalized. These symptoms vary, depending upon the severity of the injury and the degree of involvement of the other structures of the wrist. The fragments are rarely palpable. Differentiating the type of triquetral fracture is ordinarily not possible clinically and must be decided roentgenographically. It often happens that some sprains of the wrist can only be distinguished from fractures of the triquetrum by roentgenographic means.

ROENTGENOGRAPHIC FINDINGS

Triquetral fractures may be grouped as follows (Table I):

1. Fractures involving the dorsal aspect of the bone in the nature of chip, flake, traction, or avulsion fragments. They are best observed in the lateral and oblique projec-

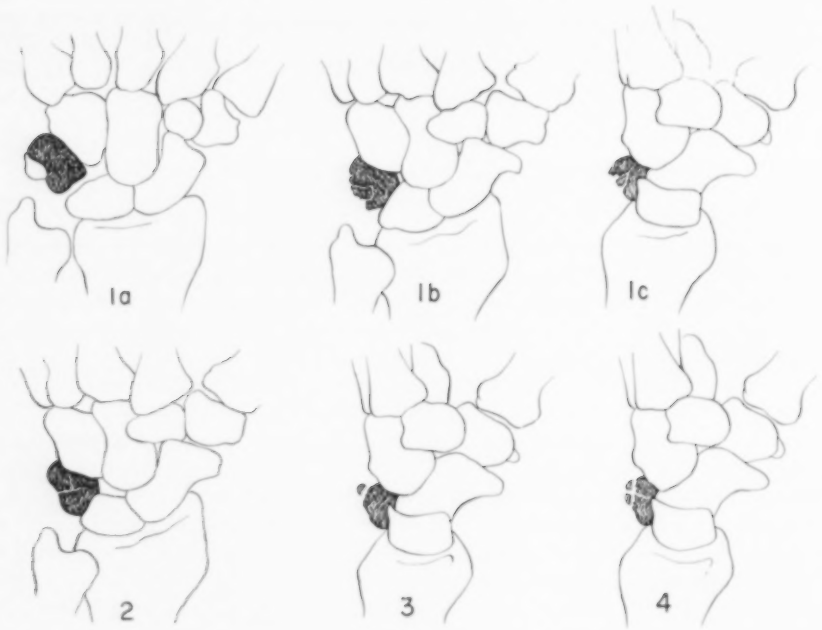

FIG. 1

Sketches copied from roentgenograms illustrating various types of triquetral fractures observed in this series.

1a, 1b, 1c: Drawings from roentgenograms of same case show necessity for multiple views. *a*, as a rule the dorsovolar view fails to demonstrate the fracture; *b*, semiprone oblique view; *c*, lateral view demonstrating comminuted fracture of body and dorsum.

Fig. 1, *2*: Semiprone oblique view; comminuted fissure fracture.

Fig. 1, *3*; Lateral view; single dorsal chip fracture.

Fig. 1, *4*; Lateral view; body fissure fracture with two dorsal chips.

tions of the wrist and they are almost never seen in the postero-anterior projection. Fragments off the dorsum of the triquetrum may be single or multiple, and may be very tiny flakes or be as large as one-third of the entire bone. These fragments are often separated or detached from the bone. When separated they very often result in non-union with rounding-off to form a permanent ossicle adjacent to the parent bone. Fragments with little or no separation ordinarily unite but this usually takes several months. Of our cases the three which showed the earliest beginning of bony union did so in six, seven, and nine weeks respectively.

2. Fractures involving the main body of the triquetrum may be described as linear, fissure, or comminuted fractures. To visualize these requires postero-anterior, lateral, and oblique roentgenograms in both planes of the wrist with the finest technical detail. They are often overlooked on casual inspection. Fissure or comminuted fractures usually occur with chip or avulsion fractures. In our series there was only one fracture of the main body of the triquetrum without an associated fracture of its dorsum. However, the more common fractures of the dorsum of the triquetrum are frequently seen without any concomitant fracture of the main part of the bone. Many fractures of the body of the bone, however, are difficult to visualize and are easily missed. It is quite probable that fissure fractures often go undiagnosed and are passed off as sprains. Unlike the much more disabling fractures of the waist of the navicular, aseptic necrosis following fractures of the body of the triquetrum is, apparently, non-existent. Non-union of this type of fracture is very rare [2] and union occurs ordinarily with no obvious gross deformity. One reason for

TABLE I

TRIQUETRAL FRACTURES
(Total Forty-Six Cases)

Category	Site	Type
Isolated triquetral fractures 32 cases (70%)	Dorsal chip: 23	Single fragment: 20 Multiple fragments: 3
	Body: 1	Linear: 1
	Body and dorsal chip: 8	Body — Comminuted: 1 Linear: 7 Dorsal chip — Single fragment: 5 Multiple fragments: 3
Combination triquetral fractures 14 cases (30%) with	Dorsal chip: 9	Single fragment: 6 Multiple fragments: 3
Radius: 9 Ulna: 3 Navicular: 2 Hamate: 1	Body and dorsal chip: 5	Body — Comminuted: 3 Linear: 2 Dorsal chip — Single fragment: 4 Multiple fragments: 1

this lack of complications may be indicated by the fact that in our series of fractures of the body of the triquetrum there were no cases of marked separation of the fragments nor was there true compression with decrease in volume of the bone. The possibility that late traumatic arthritic changes may develop cannot be ruled out because we have not followed our cases over a sufficiently long period of time to determine whether such arthritic changes do or do not occur.

TREATMENT AND CLINICAL COURSE

As Bonnin and Greening have pointed out, patients with untreated fractures may complain of persistent discomfort and the fractures are commonly diagnosed as "chronic sprain". Proper management is essential in order to reduce these "chronic sprains" to a *minimum and to accelerate functional recovery. The degree of disability is clinically* evaluated from the range of motion, strength of grip, swelling and tenderness, and, to a lesser extent, from the subjective complaints. The severity of the injury determines the

TABLE II

TRIQUETRAL FRACTURES: HISTORY AND PROGRESS *

Type of Injury	No. of Cases	Duration of Disability in Isolated Triquetral Fractures	Treatment
Fall on hand or wrist	25	2 weeks: 2 2 weeks to one month: 4 1 to 2 months: 8 over 2 months: 3	Plaster cast: 10 Strap support: 7
Direct blows to carpus	7	2 weeks: 1 2 weeks to 1 month: 2 1 to 2 months: 1 over 2 months: 1	Plaster cast: 2 Strap support: 3
Sudden resistance against twisting motions of wrist	4	2 weeks: 1 2 weeks to 1 month: 2	Strap support: 3

* There were a number of cases with either insufficient history or follow-up out of a total of forty-six triquetral fractures in this series.

treatment to be employed. The duration of treatment closely parallels the duration of disability (Table II).

1. In the clinically milder, uncomplicated triquetral fractures, a leather, elastic, or other simple wrist support for two to four weeks together with physiotherapy is generally sufficient.[3]

2. The clinically more severe cases require immobilization in a plaster cast for three to six weeks and a wrist support and appropriate physiotherapeutic measures after the cast has been removed.

3. Triquetral fractures associated with other wrist fractures are for the most part incidental and the treatment required is that for the more important injury, as in concurrent Colles' fracture or navicular fractures.

Serial roentgenograms cannot be depended upon as guides to therapy because bony union either never occurs or, in most cases, is delayed well beyond the time of clinical or functional recovery. Most patients are able to resume their usual activities a short time after the removal of the wrist support or cast despite the frequent lack of, or delay in, bony union. Occasionally, slight or minimal symptoms may persist for many weeks or even many months, but this does not often interfere with ordinary use of the wrist.

SUMMARY

1. Fractures of the triquetrum occur infrequently.

2. Chip, flake, traction, or avulsion fractures of the dorsal aspect of the triquetrum often do not unite and may form a permanent ossicle; those that do unite usually take several months to do so.

3. Fissure and comminuted fractures of the main part of the triquetrum almost always unite without gross deformity; non-union is rare and aseptic necrosis apparently does not occur.

4. It must be emphasized that clinical or functional recovery usually occurs long before roentgenographic evidence of bony union is demonstrated.

NOTE: We are indebted to Dr. S. M. Paley of the United States Public Health Service Clinic for the use of his clinical records and clinical evaluation of the cases. For the preparation of illustrations the authors are indebted to Miss Shirley Baty.

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Chondrosarcoma of the Proximal Portion of the Femur Treated by Resection and Bone Replacement

A Six-Year Result *

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Primary central chondrosarcoma of the proximal portion of the femur is sufficiently unusual to make the data of even one case of value in the management of other cases which may be encountered. In addition, the fate of the autoclaved specimen as a replacement graft and that of the later fresh autogenous tibial graft has stimulated much thought in those concerned with the phenomena of bone repair who have reviewed this material.

The patient, a married woman, twenty years and nine months of age, was admitted to the Los Angeles County Hospital on September 27, 1949, because of pain in the left thigh and knee which had been increasing since April 1949. A cane was required for walking several weeks prior to admission. Other personal history and the family history were irrelevant.

The physical examination revealed no abnormal findings except in relation to the left hip and thigh. The patient limped because pain caused moderate restriction of the active motions of the hip. Gentle passive hip motions were complete with minimal thigh discomfort. There was moderate tenderness over the upper portion of the thigh but not over the hip joint. There was 2.5 centimeters of lengthening of the extremity.

Urinalysis and blood count were within normal limits. The values for serum calcium (10.9 milligrams per 100 cubic centimeters), serum phosphorus (5.5 milligrams per 100 cubic centimeters), and serum alkaline phosphatase (3.1 Bodansky units) were not abnormal. The erythrocyte-sedimentation rate (Wintrobe) was ten millimeters. The Kahn and Wassermann tests gave negative results.

Roentgenograms revealed a radiolucent, loculated, slightly expansile lesion of the femoral head, femoral neck, and intertrochanteric region which was sharply defined by the surrounding bone of normal density. At the slightly expanded superolateral capitocervical junction, there was a small area of cortical destruction (Figs. 1-A and 1-B). Otherwise, there was no evidence of penetration of the cortex, of periosteal reaction, or of hip-joint involvement. Roentgenographic examination of the chest was negative.

On October 5, 1949, about thirty cubic centimeters of avascular, yellowish, gelatinous material was removed through a lateral exposure and drill hole at the base of the greater trochanter.

The diagnosis of chondrosarcoma of a definitely malignant and invasive character was concurred in by Hugh A. Edmondson, M.D., and other pathologists who reviewed the biopsy specimens (Figs. 2 to 6).

Treatment

All consultants agreed that treatment should consist in surgical removal of the neoplasm. The procedures discussed varied from curettement, cauterization, and bone-chip replacement to hemipelvectomy. The Hospital Tumor Board advised hemipelvectomy. At this time the case was brought to our attention. Upon reconsideration, it was agreed to withhold hemipelvectomy and to resect the proximal portion of the femur and all surrounding soft tissue which might have become involved by direct extension of the tumor or exposed by the biopsy, unless there was gross or microscopic evidence of the penetration of the articular cartilage or of the neck.

On November 25, 1949, the proximal sixteen centimeters of the left femur was resected in one piece together with the soft-tissue attachments of tendons and muscles, the biopsy operative area, the entire hip-joint capsule, and the ligamentum teres. Anteromedially at the most proximal portion of the femoral shaft, at the confluency of the vasti medialis and intermedius, a small area of hemosiderin-pigmented medialis muscle was exposed. Frozen sections were negative for tumor. The instruments were discarded and the muscle was re-entered at a lower level. Paraffin sections later showed a solitary focus of chondrosarcoma in the vastus intermedius at its confluent origin with the vastus lateralis where muscle repair and a tiny piece

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, January 30, 1955.

FIG. 1-A

FIG. 1-B

Anteroposterior and lateral roentgenograms of the proximal portion of the left femur, made on September 27, 1949, showing the destructive lesion of the femoral head, neck, and intertrochanteric region.

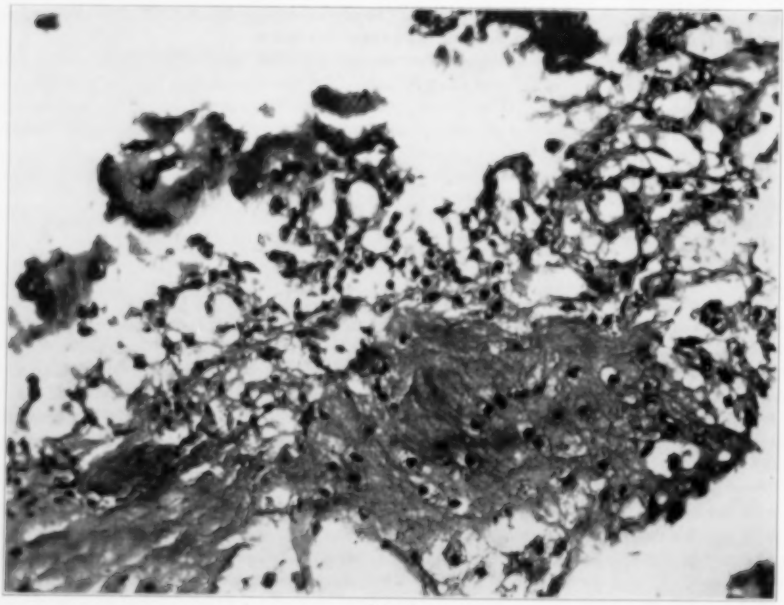

FIG. 2

The tumor cells are cartilaginous in nature; many are immature with indistinct cell borders; some nuclei are hyperchromatic and some are binucleated; many cells are relatively large and are close together (× 245).

FIG. 3

Section at the junction of the femoral head and neck (× 15). The tumor has destroyed most of the subchondral bone. The articular cartilage is greatly thinned, but its surface is intact.

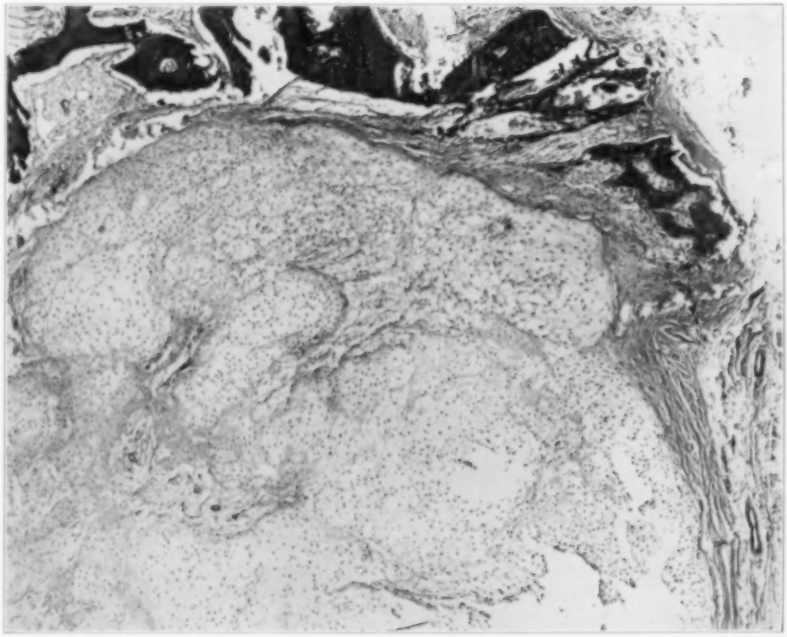

FIG. 4

Section at the junction of the superior neck and capsule showed destruction of the cortex of the femur (× 32). The periosteum-synovial membrane layers were intact, as is seen in the lower right portion of the figure.

of bone showed that this area was a portion of the biopsy operative field (Fig. 5). After section of the glutaeus medialis and the glutaeus minimus, the hip was disarticulated. This facilitated section through the psoas, pectineus, adductors, rotators, and resection of the superior portion of the musculotendinous insertion of the

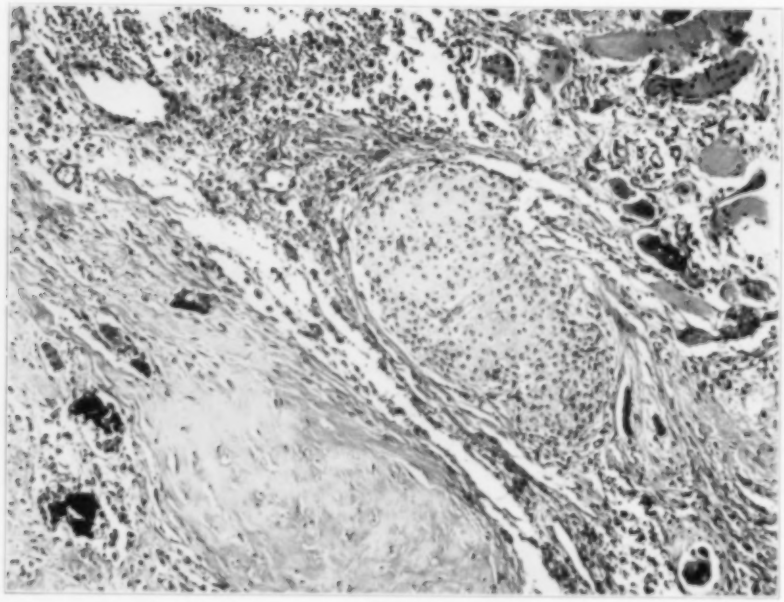

FIG. 5

Section shows tumor implant in the vastus intermedius muscle, together with muscle repair, foreign-body giant cells, tiny bone chips, and hemosiderin (× 123).

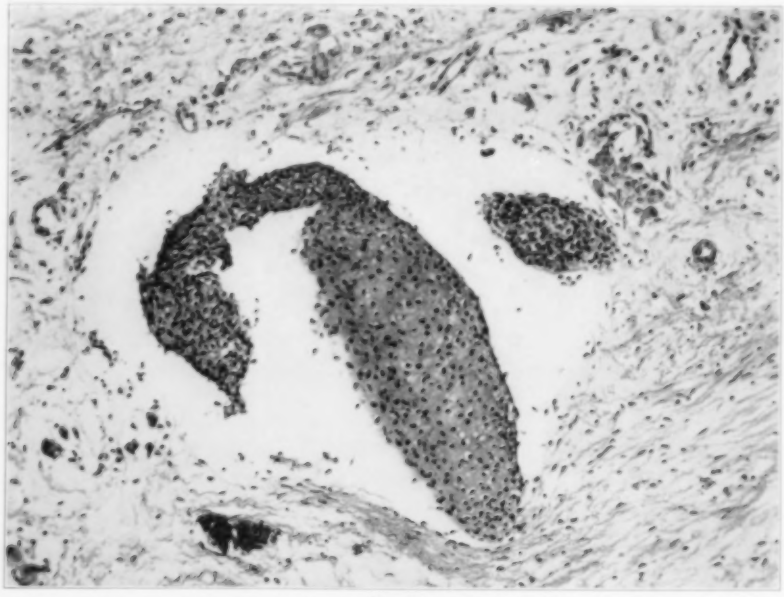

FIG. 6

Section of tumor implant at biopsy drill hole site (× 123).

FIG. 7

Fig. 7: Anteroposterior roentgenogram made two weeks after the operation on December 13, 1949.

glutaeus maximus. The tensor fasciae latae and the rectus femoris were preserved. The vasti lateralis, intermedius, and remaining medialis were sectioned circularly and were reflected distally (but not the periosteum), and the shaft was exposed for amputation of the specimen by a saw. The acetabulum was denuded to bleeding bone.

The specimen measured nine centimeters from the femoral head to the greater trochanter and twelve centimeters from the greater trochanter to the point of amputation. Additional frozen sections from the insertion of the glutaeus maximus, acetabular fat pad, superior capsule at the acetabular rim, and marrow from the distal end of the specimen showed no evidence of tumor. The round one-centimeter cortical biopsy window had not healed. Sections revealed several foci of chondrosarcoma (Fig. 6). A slight bulge, measuring 1.5 centimeters, was present on the superior aspect of the neck of the femur just at the margin of the articular cartilage of the femoral head. The cortex of the femoral neck in this area was almost completely replaced by a gray-brown cartilaginous type of tumor which had apparently extended somewhat into the femoral head beyond the articular cartilage. Sections of this area showed extensive infiltration of malignant cartilage cells. Although the cortical bone was invaded and broken, the surface of the articular cartilage was intact, and the periosteum and synovial membrane were free from invasion (Figs. 3 and 4). The entire mass of the tumor within the femoral neck and intertrochanteric region was curetted. It had the appearance of cartilage with a moderate amount of mucinous change. It extended to within five centimeters of the point of amputation, with hard cancellous bone present at this limit. Sections of the ligamentum teres showed no evidence of tumor extension. Sections of the origin of the vastus intermedius showed much hemosiderin, healing of muscle, a tiny bone chip, foreign-body giant cells, and a solitary focus of chondrosarcoma (Fig. 5). The biopsy site also showed a relatively undifferentiated highly cellular focus of the tumor (Fig. 6).

The denuded bone specimen was autoclaved for thirty minutes. In further curettement, the neck broke off easily at its base, although no fracture line had been noticed. (As seen in Figure 1-B, the lateral-oblique roentgenogram showed a questionable infraction line at the base of the neck.) A trough was made through the cortex extending from the intertrochanteric space to three centimeters above the end of the femoral shaft. The specimen was rotated so that the trough and lesser trochanter faced laterally, the shaft ends were joined by two criss-cross screws, and the greater trochanter was placed in the denuded acetabulum. Multiple fresh, autogenous iliac grafts were placed about the autoclaved bone. The fragments which had been removed from the cortex in order to make the trough were placed in the intertrochanteric space (Fig. 7). Because of the shortening and the more medial position of the replaced proximal portion of the femur, it lay in a raw bed formed by rotators and adductors and was enclosed superiorly by the stump of glutaeus medius and anterolaterally by the tensor fasciae latae and remnants of the vasti medialis and intermedius.

Three liters of whole blood and excellent anaesthesia kept the patient in good condition throughout the four and one-half hour procedure. Convalescence was uneventful.

Plaster immobilization was continued for nine months, with muscle-setting exercises, occasional cast changes, and roentgenographic examination. The limb was suspended in a splint to aid active knee motion for six weeks, when non-weight-bearing crutch-walking was permitted.

Roentgenograms showed evidence of beginning hip fusion, progressive bony union at the junction of the femoral shaft fragments, with gradual disappearance of some of the iliac bone in this area, increasing bone atrophy of the distal portion of the femoral shaft, and some reduction of the radiopacity of the graft by diffuse areas of radiolucency. At eleven months after the operation roentgenograms showed an irregular transverse intertrochanteric fracture (Figs. 8-A and 8-B).

On December 1, 1950, twelve months after the resection and the placement of the autoclaved specimen as a graft, a fresh autogenous tibial-bone graft was firmly set in a bed of vascular bone extending from the ilium across the hip joint and the fractured graft to 1.5 centimeters above the united shaft junction. The thicker, more cancellous portion of the graft was placed distally where, later, its cortex became raised above the level of its bed. Multiple iliac grafts were laid about the tibial graft.

FIG. 8-A

FIG. 8-B

Anteroposterior and lateral roentgenograms made eleven months after the operation November 11, 1950. Note the gradual filling in with bone of the medial intercortical gap at the shaft junction site, the revascularization and disuse changes, and finally the intertrochanteric fracture.

Of the two major pieces of autoclaved cortex placed in the intertrochanteric space, the short, transverse fragment was found to be loose and the longer, vertically placed piece was attached to and was vascularized by the fibrovascular tissue which had penetrated the thin cortical shell on which it lay. Several smaller pieces were partly revascularized.

The cortical edges of the bed made in the shaft portion of the autoclaved graft showed the same punctate bleeding pattern as would be expected on making a window in a normal femoral shaft. One screw was removed and a thick shaving was made across the site of shaft union. (The section was lost.) The same pattern of bleeding occurred, but it was definitely less free on the graft side (Figs. 9-A and 9-B).

Sections of the twelve-month-old autoclaved graft revealed islands of absorbing dead bone and vascular new bone. There was no evidence of chondrosarcoma.

Convalescence was again uneventful. The postoperative roentgenographic appearance of the tibial graft is seen in Figure 10.

Clinical course: A plaster cast was applied and immobilization was continued for six months. By May 25, 1951, no false motion could be detected. Roentgenographically, there appeared to be bony fusion of the hip and considerable callus incorporating the partially revascularized graft with the ilium and the two fragments of the fractured autoclaved graft (Figs. 11-A and 11-B). The cast was left off and ambulation on crutches without weight-bearing, hydrotherapy, and active resistive exercises were begun.

In August 1951, some pain and a hint of motion developed at the graft site; roentgenograms revealed a fracture of the tibial graft but with generally increased new-bone formation. A short single spica was applied. The patient continued to walk with crutches, at first without weight-bearing, then with gradually increased weight-bearing. By April 11, 1952, bony union was moderately mature (Fig. 12). In June 1952, the short spica was taken off. By July 1952, solid bony union throughout was evident and since that time the patient has been bearing full weight.

The patient has been gainfully employed as a full-time clerk-typist for the past three years. She drives a car, but it requires moderate effort to get in and out of it. She tires on long sitting and prefers chairs with arms. In October 1954, there was a ten-day period of left low-back pain, which disappeared spontaneously.

The roentgenograms of the hip (Fig. 13), made on October 8, 1954, showed that the grafts had been replaced with living bone and that new cortical, medullary, and cancellous systems, extending from the ilium to below the level of junction of the old femoral-shaft fragments, had been formed. Irregularly distributed areas of increased and diminished density in the most proximal portion of the femur indicated that the process of reconstitution was still not completely mature. No areas of bone destruction were noted.

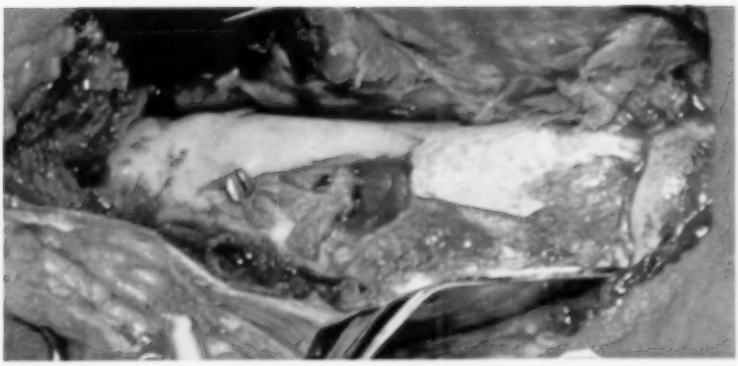

FIG. 9-A

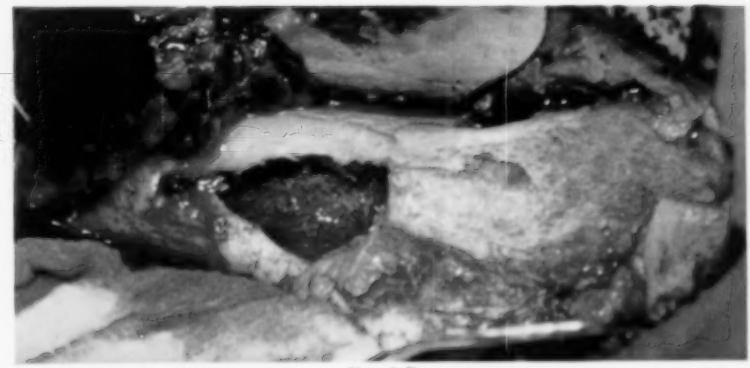

FIG. 9-B

Fig. 9-A: Shows the autoclaved graft ten seconds after moist sponging. There is slower bleeding on the graft side of the union seen at the left of the screw head.

Fig. 9-B: Shows that the screw and central bone chips have been removed. The cortical surface has been shaved off from the screw hole distally to below the shaft union site. The graft-bed site has been partially prepared. Photograph, three minutes after sponging, shows the increased bleeding of the revascularizing bone with time.

Physical examination on January 28, 1956, revealed no evidence of soft-tissue recurrence of the tumor. Roentgenograms of the chest were negative. Roentgenograms of the pelvis and proximal portion of the left femur showed further maturation of the cancellous, cortical, and medullary pattern of the bone grafts and arthrodesed hip. The left hip is fused in 20 degrees of flexion, 10 degrees of abduction, and 20 degrees of external rotation. The knee can be actively extended to 178 degrees and flexed to 125 degrees. The lower extremities are now of equal length; the circumference of the left upper thigh is nine centimeters less, mid-thigh five centimeters less, and left calf one centimeter greater than the corresponding measurements of the right lower extremity.

DISCUSSION

The biopsy provided sufficient material to establish the diagnosis of chondrosarcoma. Perhaps a more accurate evaluation of its aggressive nature, as shown by subsequent sections at areas of growth and invasion, would have been possible if a core or block of tissue including the invaded bone could have been obtained.

The adventitious foci of the tumor at the biopsy site and in the vastus intermedius show that the threat of local dissemination was real. It is evident, therefore, that the extent of the biopsy procedure should be as limited as possible when resection is still to be considered.

Hemipelvectomy was thought to provide the widest possible margin of safety. To many persons, mutilation and disability do not appear too great a price to pay for life. However, if the neoplasm were still within an envelope of normal tissue, particularly at the critical area of the femoral head and neck, then resection would also save life and suitable replacement would permit weight-bearing. Had a break-through occurred, hemipelvectomy could still have been performed.

The thin layer of normal tissue covering the invaded bone of the superior portion of the femoral head and neck indicates how vital a factor time can be. Many months (probably years) of tumor growth must have occurred before the patient suffered any symptoms. Then, five months of increasing pain and disability elapsed before medical aid was sought; and still more time was necessary to establish the diagnosis, to decide upon treatment, and to render definitive treatment.

The hemosiderin-stained vastus medialis muscle emphasizes that one can hardly be too generous in allotting a "safe" margin in resection. The possibility of local recurrence can only be answered by the passage of time and recognized in time by regular examination.

At the time of resection, a healthy woman of the patient's age has a life expectancy of forty-one and a half years. If she is still alive at sixty-one and a half years of age, there would be an additional thirteen and a half years of life expectancy. Therefore, assuming that a cure of the neoplasm could be achieved, it is evident that no prosthetic device could be expected to provide function for any considerable part of her life expectancy. Successful bone replacement and hip fusion, however, would give the patient a permanently useful limb.

The autoclaved specimen was used as the initial replacement graft because it was structurally perfect for the situation, easily secured to the distal shaft by only two screws, and could be relied upon to maintain length for sufficient time to permit observation in order to determine the relative degree and location of revascularization, absorption, and new-bone formation. These in turn would indicate the need for subsequent bone-grafting.

A comparison of the two major grafts shows a general similarity of events. The environment of the autoclaved bone was raw muscle and living bone at the acetabulum and lateral portion of the femoral-shaft junction. Medially, there was a gap between the cortices. The fresh tibial graft lay in a bed of partially revascularized bone with its proximal end in normal iliac bone, but distally, the graft was raised from its bed so that there was also a gap between its cortex and that of the revascularized autoclaved bone.

FIG. 10

Fig. 10: Tibial graft as seen roentgenographically on December 12, 1950. Note that its distal end has become raised from its bed so that there is again an intercortical gap between the graft and its bed.

In both instances, revascularization, filling in by bone of both intercortical gaps, absorption of old cortices with reformation of a single new cortex, the fact of fractures after eleven and eight and a half months, respectively, and healing, all occurred in a remarkably similar manner and time, especially when one considers the differences in size and initial environment of the two grafts. A gross difference, as observed roentgenographically, was that of the interstitial replacement of the

FIG. 11-A

FIG. 11-B

Anteroposterior and oblique roentgenograms made on May 25, 1951, six months after the insertion of the fresh tibial graft. Note non-union of fracture of the old graft and the bone production about the tibial graft. Callus fills and bulges about the intercortical gap at the distal graft site.

FIG. 12

FIG. 13

Fig. 12: Oblique roentgenogram made on April 11, 1952, sixteen and one half months after insertion of the tibial graft and twenty-eight and one half months after placement of the autoclaved graft. Note bulbous callus about fracture sites of both grafts.

Fig. 13: Roentgenogram made October 8, 1954, four years and ten and one-half months after resection and placement of the autoclaved autogenous graft.

autoclaved bone as compared with the pronounced osteoplastic response about the fresh graft. However, when revascularization of the autoclaved bone fracture ends had progressed sufficiently, a somewhat bulbous callus developed similar to the callus seen in the fracture of the tibial graft (Fig. 12).

Once new bone was formed, whether it was an interstitial or osteoplastic response about a graft or fracture, it responded to stress by the development of cortical and cancellous patterns by absorption and growth, without regard to its origin or site.

The iliac-bone shavings which had been placed just above the shaft junction were partially absorbed without participating in the shaft union. Several shavings in near contact became incorporated in the new shaft. One piece not in contact with bone was still evident over six years later. The fresh shavings placed about the hip at both grafting operations appeared to have participated in the pattern of new-bone formation.

The restricted knee motion is a great additional handicap. It occurred in the first few months of immobilization. The prolonged immobilization is thought to have been most important in preventing interruption of the revascularization and metaplastic changes responsible for the successful result. In retrospect, it appears that providing for motion by a removable portion of the cast from the knee to foot would not have jeopardized the outcome unduly.

CONCLUSIONS

The case reported shows that time may leave an extremely narrow margin of safety in a presumably resectable malignant lesion. It demonstrates that the biopsy field must be regarded as part of the tumor area and that the surgeon can hardly be too generous in allowing a "safe" margin of resection. The response to the autoclaved autogenous bone graft compared favorably with that obtained with fresh autogenous bone.

DISCUSSION

Dr. J. Vernon Luck, Los Angeles, California: This report by Dr. Thompson is far more than a case study of chondrosarcoma of the upper portion of the femur; it clearly defines the indications for local excision of the tumor as against indications for extremity ablation. It is important to differentiate clearly the osteogenic sarcomata, that is, osteosarcoma, chondrosarcoma, and fibrosarcoma of bone, since their clinical response is quite different. Osteosarcoma is truly a catastrophic occurrence, and there is some question as to whether any of the patients with this neoplasm survive, regardless of the time of treatment or the degree of radical therapy employed. In contrast to this, chondrosarcoma tends to grow slowly and to remain locally confined for long periods. With proper treatment there is, frequently, reasonably good prognosis. The same may be said of the fibrosarcoma. In both, there is naturally a wide variation in the degree of anaplasia and the rate of growth of the tumor; these factors, as is so well known, mean a great deal in the response to therapy and the prognosis.

Dr. Thompson has clearly described a technique for utilizing large areas of a bone that has become the host to a malignant primary tumor. In wide resections of this type, it should be helpful in a number of instances, to utilize this technique. There is reason to believe in studying this case that the response to autoclaved autogenous bone is second only to the response to fresh autogenous bone. This paper has presented a splendid description of the pattern and rate of revascularization of both the autoclaved bone and the fresh autogenous bone. There is here an unusual opportunity to compare the value and rate of regeneration of these two types of bone grafts.

There are those who will wonder if a prosthesis replacing the entire upper portion of the femur would not have allowed as good function as the bone-grafting and fusion. Considering the age of this patient and her life expectancy, I think most of us will agree that fusion was the operation of choice. It has been my opportunity to observe the patient personally on numerous occasions from the time of operation to the present; we are impressed with the management of this difficult problem.

We must ask ourselves if there is still danger of local recurrence of this tumor. No doubt there is some small degree of possibility of local recurrence but this possibility must be exceedingly small. Further, if this tumor should recur, it probably will recur as slowly growing tissue, and there will be ample opportunity for either another local excision or, if the tissue shows characteristics indicating a highly aggressive character, radical ablative surgery.

In local excision of this type, it is of the greatest importance, as pointed out by Dr. Thompson, to excise the entire tumor including the adjacent soft tissues; it was fortunate in this instance that the tumor had not

perforated the periosteal layer. The biopsy performed in this patient was probably somewhat more extensive than would have been necessary but it appears that no irreparable harm was done. Had the tumor broken through the periosteum and extensively invaded the overlying soft tissues, then a hindquarter amputation would have been indicated; particularly so, if the tumor were rapidly growing. It is probable that the central type of chondrosarcoma is more amenable to local excision than is the peripheral type.

It is not remarkable that we, as orthopaedists, earnestly seek methods of dealing with bone tumors by resection rather than by extremity ablation. Our work for the most part is reconstructive; we strive to preserve tissue and to develop the utmost function and to achieve the best cosmetic result possible. It is, therefore, against our nature to destroy an entire extremity. It is a decided advance and an important achievement when we can find means for saving an extremity, particularly in a young person. However, we must not find ourselves thinking more intently on saving the extremity than on saving the patient's life. It is, however, increasingly evident that more damage is created in the management of bone tumors by overdiagnosing and overtreating than by underdiagnosing and undertreating.

Surgery is the only treatment that can be successfully employed in the treatment of chondrosarcoma. Roentgen therapy is not useful in the cure of this tumor. In making the decision regarding the extent of the surgery required, one must take into consideration more than the microscopic picture. Here, indeed, is a tumor whose management requires a clear correlation of the clinical findings, the roentgenographic features, and the pathological picture. There are times that the large, slowly growing, low-grade chondrosarcoma is erroneously diagnosed as chondroma. It can be said that whenever one of these tumors exists in an adult and is growing, even though that growth be slow, it had best be looked upon as a chondrosarcoma, irrespective of benign microscopic appearance.

Once chondrosarcoma has been diagnosed, treatment should not be long delayed. While chondrosarcoma grows extremely slowly over a period of years, such a tumor has been observed on a number of occasions to suddenly change and to become, in a very brief period of time, aggressive and highly malignant with early metastases. Some have attained incredible size. We have had one case at the Los Angeles County Hospital—a chondrosarcoma of the ilium—which was identified as such when it was the size of a hen's egg; the patient refused therapy, and the tumor grew until it was larger than a football. At this time the patient requested treatment, and a hindquarter amputation was carried out with much difficulty. Here, the prognosis was certainly not good.

Treatment of Ununited Fracture of the Carpal Navicular by Styloidectomy of the Radius*

BY LYMAN SMITH, M.D., ELGIN, ILLINOIS, AND BARRY FRIEDMAN, M.D., CLEVELAND, OHIO

A patient presenting a painful stiff wrist, secondary to an ununited fracture of the carpal navicular, warrants a substantial degree of concern. He is usually young and vigorous and is hindered by the condition which is usually longstanding; the wrist is weak and painful and the best method of treatment is uncertain. A study of the extensive literature on the subject is not conducive to peace of mind for the surgeon — there are too many alternatives. Each is highly recommended by the individual author, but all are found wanting in some degree by various other authors. An examination of each method is not indicated here, instead we shall only list them: excision of one or both fragments [2, 8], excision of the proximal carpal row [9], prolonged immobilization [11], internal screw fixation [5], insertion of a prosthesis [4], drilling of fragments [8], intercarpal arthrodesis [10] or radiocarpal arthrodesis [11], bone-grafting [6], and bone-grafting with styloidectomy of the radius [1]. To this long list we would add another procedure for consideration — radial styloidectomy alone. Our results with this method have not been satisfactory in all cases, and we make no pretense of presenting here a final answer to this vexing problem. However, the results obtained by this simple procedure have been so gratifying in so many of the patients, despite severe arthritis, that we wish to present the procedure as a method worthy of consideration and further study.

In 1948, Barnard and Stubbins published a preliminary report on the results following excision of the radial styloid process, after which they had used the excised portion as a bone graft; they obtained union and good results in all of their nine cases. They recognized that mechanically the styloid process played an irritating role as it impinged on the distal fragment of the navicular in radial and dorsal deviation of the wrist. In three malunited cases, their only treatment was to remove the styloid process, but good results were obtained. The approach to the problem as described here, has been different in that we have ignored the non-union and other changes and have simply excised the styloid process in all cases. Our series consists of thirteen patients; the first styloidectomy was carried out in April 1950, the latest in April 1954. The series is small, and the elapsed time is short, but from a study of these, we feel that the importance of the relationship of the radial styloid to non-union of fractures of the navicular has been underestimated in the treatment of ununited fractures of the navicular.

Schnek recognized the role of the radial styloid process in the production of fractures of the carpal navicular bone and described the impingement of the process against the waist of that bone in forced radial deviation and dorsiflexion of the wrist. Figure 1-A illustrates the continuing importance of the radial styloid process after fracture. These roentgenograms were made in radial and ulnar deviation and show an ununited fracture of four years' duration. There is elongation or "sharpening" of the styloid process with the formation of a spur on the distal navicular fragment. In radial deviation, these points appear to touch. However, at operation they were found actually to overlap. The styloid spur fitted nicely into a concavity just proximal to the projection on the distal fragment. As in most of these cases, this patient complained particularly of pain initiated by radial and dorsal deviation of the wrist. Three weeks following excision of the styloid process (Fig. 1-B), he

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, January 31, 1955.

was able to pole-vault in a school track meet with no complaint of pain. We do not know what the prognosis will be. The non-union itself has not been treated, but it is common knowledge that pseudarthroses in other bones are often painless.

Figure 2-A shows marked changes in a wrist. The patient was a hairdresser, fifty years old, who had suffered an injury to the wrist twenty years previously. He complained of increasing pain and considerable stiffness, sufficient to make him consider changing occupations. The x-ray and clinical findings revealed a condition of such severity that it was deemed proper to suggest arthrodesis of the wrist. However, the patient objected to the prospect of a long period of postoperative immobilization and the resulting complete stiffness of the wrist. The obvious elongation of the radial styloid was correlated with his complaint of particular pain on radial deviation. Accordingly, the possibilities

FIG. 1-A

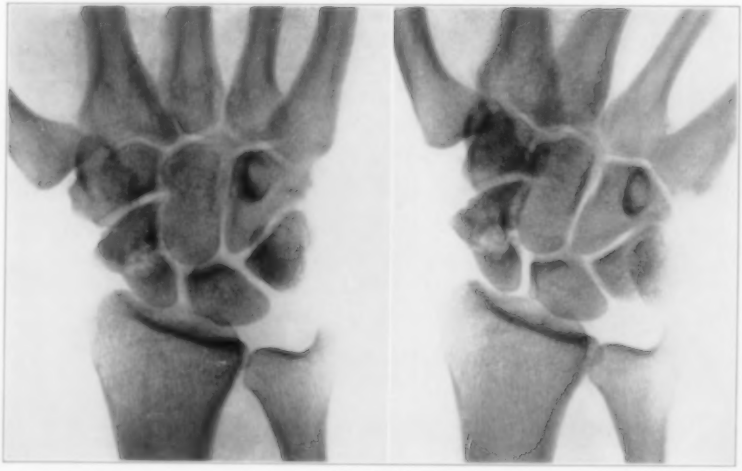

FIG. 1-B

Fig. 1-A: Case 1. Roentgenograms made in radial and ulnar deviation. Fracture of four years' duration with the formation of "kissing spurs" between the styloid process and distal navicular fragment is shown. The particular complaint was pain on radial deviation of the wrist.

Fig. 1-B: Postoperative roentgenograms. The styloid process was removed with complete relief of pain.

were explained and styloidectomy alone was recommended as at least a hope of ameliorating the symptoms. Arthrodesis was held in abeyance. Styloidectomy was done in August 1950. Figure 2-B, roentgenograms made in radial and ulnar deviation, showed the result in March 1954. The results exceeded expectations; indeed, he has an excellent wrist. It is painless with a normal range of motion and he has a strong grasp. However, the roentgenograms still demonstrate marked changes. In fact, all of the findings described by various authors as being the cause of pain in this condition were present in this patient—aseptic necrosis of the fragments, vacuolization, loss of joint space, and spur formation (there was no sharpening of the radial styloid, the process having been excised). It would seem to us that the most apparent explanation of the good result is on a mechanical basis, that is, the pointed styloid process had acted as a probe stabbing the distal navicular fragment on particular motions of the wrist.

FIG. 2-A

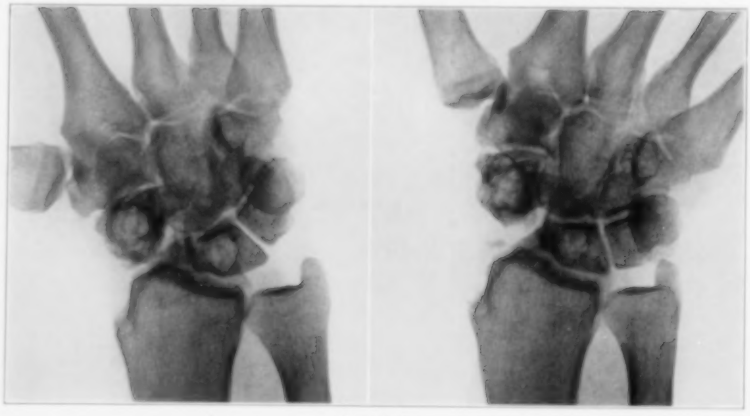

FIG. 2-B

Fig. 2-A: Case 2. Marked changes twenty years after fracture. There was severe pain and stiffness.

Fig. 2-B: Three years following styloidectomy, there is a painless, strong wrist with a normal range of motion. Roentgenograms were made in radial and ulnar deviation.

Figure 3-A is a roentgenogram of another wrist which shows rather marked changes. Marginal spurs are quite prominent and changes include a loose body in the ulnar side of the joint. The result, however, has been excellent after styloidectomy was performed in January 1953 (Fig. 3-B).

In three of our patients, the results have been unsatisfactory. Two complain of pain and stiffness as severe as that prior to the styloidectomy. Radiocarpal arthrodesis has been suggested to them. In the other patient, a fair result is considered to have been obtained in that the range of motion is good and the tenderness over the navicular has been lost; but there is pain at the extremes of dorsal and palmar flexion and he is unable to engage in strenuous activities. All three of these patients have marked displacement of the distal fragment. Lateral and oblique roentgenograms of these wrists showed a disturbance

FIG. 3-A

FIG. 3-B

Figs. 3-A and 3-B: Case 4. Preoperative and postoperative roentgenograms were made in the position of radial deviation. Preoperatively there were marginal spurs, loss of articular cartilage, non-union, and a loose body in the ulnar side of the joint. All symptoms were relieved by styloidectomy.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 9. Poor result. There is an abnormal relationship between the capitate and semilunar, as well as considerable displacement of the distal fragment.

Fig. 4-B: Lateral roentgenogram showing anterior shift of the semilunar.

TABLE I

Case, Age, and Occupation	Duration of Fracture	Date of Operation	X-Ray Findings	Preoperative Range of Motion of Wrist*	Postoperative Range of Motion of Wrist*	Postoperative Symptoms	Results as of December 1954
1. D.T. 19 Student	Four years	March 1954	Pointing of styloid No displacement of fragments Cavitation at fracture site	D: 50 P: 50 Ab: 5 Ad: 30	D: 70 P: 60 Ab: 20 Ad: 30	Absent	Excellent
2. J.F. 50 Hairdresser	Twenty years	August 1950	Pointing of styloid Marked displacement of fragments Vacuolization of fragments and lunate Loss of joint space Aseptic necrosis	D: 30 P: 20 Ab: 0 Ad: 10	D: 70 P: 70 Ab: 20 Ad: 30	Absent	Excellent
3. W.M. 22 Clerk	Two years	July 1951	Pointing of styloid No displacement of fragments Cavitation Aseptic necrosis	D: 30 P: 55 Ab: 5 Ad: 10	D: 70 P: 70 Ab: 15 Ad: 25	Absent Some pain on extremes of motion for year postoperatively	Excellent
4. G.W. 34 Clerk	Two years	January 1953	Pointing of styloid Displacement of fragments Loss of joint space	D: 50 P: 60 Ab: 5 Ad: 5	D: 70 P: 60 Ab: 15 Ad: 5	Slight tenderness to pressure, ulnar side of wrist anteriorly	Excellent
5. E.G. 63 Laborer	Thirty-four years	April 1950	Marked pointing of styloid Eburnation of styloid process Displacement of fragments Aseptic necrosis Loss of joint space	D: 30 P: 40 Ab: 0 Ad: 30	D: 60 P: 50 Ab: 20 Ad: 30	Absent	Excellent
6. J.Y. 31 Laborer	Unknown	July 1953	Pointing of styloid Marked displacement of fragments Vacuolization of fragments Aseptic necrosis	Not measured All motions markedly restricted	D: 70 P: 60 Ab: 20 Ad: 30	Absent, save for clicking sensation in wrist	Excellent
7. C.S. 28 Stagehand	Three months	October 1952	No displacement of fragments Cavitation at fracture site	D: 40 P: 20	D: 60 P: 45 Ab: 10 Ad: 30	Absent	Excellent

TABLE I *(Continued)*

Case, Age, and Occupation	Duration of Fracture	Date of Operation	X-Ray Findings	Preoperative Range of Motion of Wrist*	Postoperative Range of Motion of Wrist*	Postoperative Symptoms	Results as of December 1954
8. A.L. 33 Carpenter	Ten years	January 1954	Pointing of styloid Marked displacement of fragments Cystic changes	D: 10 P: 15 Ab: 5 Ad: 10	D: 10 P: 15 Ab: 5 Ad: 10	Pain and stiffness recurred when returned to heavy work	Poor
9. W.C. 38 Farmer	Three years	February 1954	Marked pointing of styloid Displacement of fragments	D: 55 P: 60 Ab: 0 Ad: 20	D: 10 P: 60 Ab: 0 Ad: 20	Pain and stiffness recurred when returned to heavy work	Poor
10. J.S. 19 Student	One year	July 1953 Reoperated August 1954 for excision of portion of displaced distal fragment	Pointing of styloid Marked displacement of fragments Vacuolization	D: 10 P: 30 Ab: 5 Ad: 20	D: 85 P: 55 Ab: 25 Ad: 35	Pain with extremes of dorsiflexion and palmar flexion	Fair
11. H.B. 39 Glazier	Fifteen years	December 1953	Pointing of styloid No displacement of fragments Aseptic necrosis Loss of joint space	D: 45 P: 30 Ab: 5 Ad: 5	D: 60 P: 30 Ab: 15 Ad: 15	Absent	Excellent
12. B.K. 58 Laborer	Eight months	October 1952	Pointing of styloid No displacement of fragments Cavitation at fracture site	D: 60 P: 30 Ab: 5 Ad: 10	D: 80 P: 60 Ab: 15 Ad: 25	Absent	Excellent
13. C.F. 32 Housewife	Four months	April 1954	Marked displacement of fragments	Not recorded	D: 60 P: 55 Ab: 15 Ad: 20	Absent	Excellent

* D: dorsiflexion; P: palmar flexion; Ab: abduction; Ad: adduction.

in relationship of the capitate and lunate consisting of a posterior displacement of the former and an anterior displacement of the latter (Figs. 4-A and 4-B). Dwyer, in commenting on his results following total excision of the navicular, noted them to be least satisfactory in patients with such a disturbed carpal relationship. However, in our ten pa-

tients with satisfactory results, five demonstrated such changes to as great a degree; its significance, therefore, in prognosis is not definite. We can only say that all five patients without displacement obtained an excellent result while in eight patients with displacement, the results in three were disappointing.

Barnard and Stubbins pointed out that, in the normal wrist, the tuberosity of the navicular moves anterior to the radial styloid process on radial deviation of the wrist. However, following fracture of the navicular, the distal fragment moves with the distal carpal row and butts against the styloid process, with resulting hypertrophic changes at these two kissing points. Our observations at surgery and following experimental fracture of the navicular in the cadaver confirm this statement, and we feel that this abnormal contact is apparently the prime cause of pain in these cases.

It might be theorized that removal of the entire navicular or its distal fragment should be as successful in relieving painful impingement. However, Ian Kitchin has reported a case in which, following total excision of the navicular, the elongated styloid process caused pain by contacting the trapezium.

OPERATIVE TECHNIQUE

The radial styloid process is approached through a one and one-half inch incision placed directly over its center. The cephalic vein is retracted dorsally and the superficial branch of the radial nerve is identified as it courses over the deep fascia overlying the styloid process. The short extensor and long abductor tendons of the thumb are freed from their attachments to the dorsal ligament of the wrist and are retracted volarward along with the radial artery, which is seldom seen in the operative field. The radial styloid is then freed subperiostally for a distance of about one inch. Attached to its distal tip is the capsule of the wrist joint which is thickened to form the radial collateral ligament. This is incised in the direction of the long axis of the thumb, and the navicular is exposed. The distal fragment of the navicular is seen abutting the tip of the styloid with the wrist in even slight radial deviation. Removal of the styloid process is accomplished by an osteotomy across its base at a point which is just proximal to the fracture line with the hand in radial deviation. Following this, the fracture line is clearly seen and the distal fragment of the navicular will be found to move free of impingement on the distal portion of the radius. In closure, the capsule of the radiocarpal joint is sutured over the cut bony surface of the radius and is interposed between the bone and the tendons of the volar side of the wrist. The plaster splint is removed after a week to ten days, and active motion is started. We would caution against injury to the superficial branch of the radial nerve, as in one of our patients an annoying paraesthesia persisted over its distribution for some months.

If the cosmetic result is of particular importance, the skin incision can be placed transversely rather than longitudinally. We would suggest a generous removal of the styloid for in none of our patients have we noted any residual instability of the wrist.

SUMMARY AND CONCLUSIONS

A small series such as this does not warrant definite conclusions, but it is suggested that the pain associated with an ununited fracture of the carpal navicular is primarily occasioned by the impingement of the radial styloid process against the distal navicular fragment. Excision of the styloid process has given excellent results in ten patients up to the present time; fair results have been obtained in one and poor results in two. The procedure is simple and convalescence is short. If the operation is unsuccessful little has been lost and any of the more radical surgical procedures may be used.

NOTE: We are indebted to Dr. Joseph Brown of Cleveland, Ohio, and to Dr. Earl Leimbacher of Joliet, Illinois, for cases contributed to this series.

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DISCUSSION

Dr. Leonard Barnard, Oakland, California: As so often happens, that which is thought to be new in surgery turns out to have been done by others before. In 1948, after the publishing of the paper which Dr. Stubbins and I presented to The Academy on the use of styloidectomy in the treatment of non-union of the carpal navicular, I received a small reprint from Mr. Ian D. Kitchin describing his results in the use of styloidectomy and excision of the carpal navicular in a group of English coal miners with non-union of the carpal navicular. His results were excellent, and a large percentage of the patients returned to work in the mines.

My own experience with the method is somewhat limited. I have observed excellent results when the procedure was performed for malunion of the carpal navicular. I have also had a few cases in which the procedure was performed for non-union in which the graft failed to unite; these were clinically much improved.

It is my impression that in addition to removing the styloid process, a relatively local synovectomy and neurectomy are done which contribute to the success of the procedure. Otherwise I believe it would be difficult to explain the results in some of the patients who show considerable arthritic change about the joint.

While I feel that the approach has much merit, I cannot believe it will supplant the occasional use of arthrodesis of the wrist when the degree of arthritic change is severe. However, it could well be done as a preliminary procedure. There will also be times when the removal of a small proximal fragment of the navicular is preferred in the absence of extensive arthritic change. Fixation methods, either by grafting or with pins, cannot be abandoned.

Dr. Ralph Soto-Hall, San Francisco, California: Non-union of the carpal navicular is a very complex problem, which will not be solved by any one surgical procedure. The solution, the choice of operation, depends upon the size of the fragments, their vascular supply, duration of the non-union (because in some there is a severe mechanical arthritis), and on the degree of mobility existing at the fracture line. Obviously when there are marked arthritic changes, the cure will not be accomplished by treating the pseudarthrosis: carpal arthrodesis will probably be necessary. In early cases, a fundamental difference exists between those in which there is articular cartilage between the fragments and those in which there is fibrous union. We have devised a method of determining the degree of non-union before operation. The method consists in applying traction of about thirty-five pounds to the wrist. [Dr. Soto-Hall showed slides demonstrating his method of applying traction.] By means of traction, the degree of fibrous union can be determined. In cases with great mobility, we completely excise the contact surfaces. While they are separated we introduce an intramedullary bone graft, without damaging the articular cartilage or the blood supply. I think that this traction method could perhaps be applied to this series in order to determine whether mobility can be studied after styloidectomy. Obviously patients with a long, sharp, pointed styloid would be benefited by its removal. I would like to ask one more question. What is the possibility that migration will take place with time after the removal of a sizable part of the styloid process? We know for instance that, after excision of the carpal navicular, there will be migration.

I believe that styloidectomy will be a great adjunct to the other procedures in the treatment of this condition, but we must individualize our treatment. I think that the authors have a wonderful opportunity now to study these cases to see whether mobility of the fragments may not be one of the factors in the few failures that they have had.

Dr. Friedman (closing): I was glad to hear Dr. Barnard say that his experience had been favorable in a few cases in which he had done styloidectomy. Dr. Soto-Hall's comment regarding the use of traction in order to determine if the fibrous union of pseudarthrosis exists is undoubtedly of definite value and we intend, in a review of our cases, to use traction to see if we can correlate our results with the presence or absence of mobility. When this series becomes larger, we may be able to determine the type of fracture of the carpal navicular which may be best treated by a simple styloidectomy. It is true that there will be failures in this type of procedure: so far we cannot tell which ones will fail. However, there is so much to be gained and so little to be lost by attempting this procedure that we feel that its use may salvage some wrists which might otherwise have to be fused.

DISCUSSION

Immunological Factors in Homogenous-Bone Transplantation

(Continued from page 336)

Recently I looked back over the records of our bone bank to see what information could be obtained on the compatibility or incompatibility effect of blood groups between the donor of the graft and the host. It was only with a good deal of effort that I was able to unearth statistical information on a total of twenty-six cases.

There were twenty cases of lumbar fusion for low-back pain. All of the fusions extended from the fourth lumbar vertebra to the sacrum and were done by our regular technique with a bone-bank graft of cortical bone and a metallic plate to provide internal fixation. In three cases of this group, there was complete incompatibility of the blood of the donor and host, with respect to both major and minor factors, and yet all of the grafts healed. In ten cases, major incompatibility of the blood types existed, but there were no failures. Minor incompatibility was present in five cases, and these included two failures. There were no failures in the two cases in which there was complete compatibility of blood types.

In six cases of spine fusion for scoliosis, major incompatibility of blood types existed in four, and all of the fusions healed well except one in which there was a questionable pseudarthrosis. In two cases, there was minor incompatibility of blood types but there was no failure of healing. While this series is small, it is nevertheless convincing, showing that blood-type incompatibility is not a factor in the failure of healing in homogenous-bone grafts.

If the factor of incompatibility of blood types does not explain the difference between healing of homogenous and autogenous bone grafts, where else may we look to find the answer? It seems to me that we must next study the proteins in bone to see whether or not they are specific for different individuals and to see whether or not there is any evidence that these may build up an antigenic reaction in the body of the host. I still have confidence in the bone-bank graft if it is used to fill a bony cavity or if the graft is in contact throughout its entire extent with the host bone, but I do not think that it is as good as autogenous bone when a gap has to be bridged. In that case, I would use autogenous bone because, as Sir Reginald Watson-Jones once said, "When I implant a bone graft, I want bone that will fight for me."

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Dr. Curtiss (closing): Dr. Ray considers that slides of his own work also show evidence of rejection of the homogenous-tissue transplants by the host. This reaction to transplants has been the subject of a great deal of research by men working with soft tissues, especially, as Dr. Wilson has mentioned, the plastic surgeons. Dr. Wilson has presented us with another challenge. We did not expect at the beginning of this investigation that we would find the answer to the tissue incompatibility of either a slight or marked degree in the difference between blood types. However, in a review of the literature, we could find no reported evidence (other than clinical impression) that the blood-type incompatibility did or did not make a difference. In addition, we could find no reports of objective experiments, and for that reason this work was undertaken. We considered that this experiment should simply clear away one bit of underbrush if possible before experiments with other factors involved in possible antigen-antibody reaction to homogenous bone were undertaken. Dr. Wilson has mentioned a study of bone proteins; this is a very fertile field of study, and a great deal of work needs to be done, should be done, and I hope will be done on the protein of bone.

The Anatomy of Lumbosacral Posterior Rami and Meningeal Branches of Spinal Nerves (Sinu-Vertebral Nerves)

With an Experimental Study of their Functions * †

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INTRODUCTION

Since the establishment of disease of the intervertebral disc as a major cause of low-back pain and sciatica, there has been renewed interest in the mechanism of pain production. A number of investigators believe that lumbosacral pain and muscle spasm are due to the stimulation of nerve endings in the posterior longitudinal ligament or annulus fibrosus, or both. There is also evidence that other vertebral structures and tissues, such as periosteum, ligaments, joints, fascia, and, perhaps, muscle, may be the site of pain when the disc is diseased. Published reports on the nerve supply of these structures, however, are generally incomplete and leave many questions unanswered.

Luschka was apparently the first to describe in any detail a recurrent branch of the spinal nerves which re-entered the spinal canal and supplied bone and blood vessels. He named this the sinu-vertebral nerve. He described its connections with the sympathetic system in detail, but pointed out that it was derived mainly from the spinal nerve. He described normal variations in origin, as did Wiberg recently, and indicated that there might be intersegmental anastomoses of branches from these nerves. He was unable to find branches to the disc.

Hovelacque studied the sinu-vertebral nerves of the cervical, the thoracic, and, to some extent, the sacral regions, but he dealt very little with those of the lumbar region. As did Luschka, he described their sympathetic connections. He believed that these nerves supplied dura mater and ligaments, as well as blood vessels.

In 1939, Spurling and Bradford included in their paper an illustration showing the sinu-vertebral nerve, and subsequently used it in their book.[2] This illustration was based on data obtained from Roofe, who shortly thereafter published an account of this nerve, but without the diagram. Roofe found strands entering the spinal canal by way of the lumbar intervertebral foramina, but he was not sure, even from histological examination, that they were nerves. With silver stains, however, he found non-myelinated fibers in the deep portions of the posterior longitudinal ligament and the annulus fibrosus. He was cautious in his statements about the gross distribution of the sinu-vertebral nerves, and others seem to have read more into his paper than is warranted. The illustration referred to previously is of interest because it shows sinu-vertebral nerves descending for two segments, without any ascending branches. Luschka's illustrations show ascending branches very clearly, and recent papers[16,33] show similar arrangements.

Although most authors assume that the sinu-vertebral nerve carries sensory fibers, there is little specific information concerning the types of fibers present. In commenting on microscopic studies of the nerve, Luschka described myelinated fibers. Wiberg saw

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"nerve fibers" only in the posterior longitudinal ligament, while Ehrenhaft described "nerve bundles" in the annulus, as well as beneath the posterior longitudinal ligament. From his illustrations, one cannot be certain that the nerve bundles are actually in the annulus. Tsukada [31,32] described both myelinated and non-myelinated nerve fibers in the annulus fibrosus. His illustrations also show large nerve bundles, but again one cannot be certain that they are actually in the annulus. He claims to have found nerve fibers in the notochord and the nucleus pulposus. Jung and Brunschwig found non-myelinated fibers beneath the anterior and posterior longitudinal ligaments, and Roofe described non-myelinated fibers in both the annulus and the ligament.

Therefore, there is still confusion regarding the distribution of the sinu-vertebral nerve and the types of nerve fibers it carries.

Our knowledge of the distribution of the posterior rami of the spinal nerves is also incomplete, particularly as regards their possible supply of intervertebral joints and their segmental nature.

Although Luschka and Rüdinger described branches to these joints, current textbooks rarely mention them. Badgley, in discussing a dissection by McCotter and Strong, stated that they were unable to trace branches to the joint capsule.

The present study was undertaken in order to determine as accurately as possible the distribution of the lumbosacral posterior rami and the sinu-vertebral nerves. Experimental studies were also carried out. Their purpose was to determine the effects of mechanical and electrical stimulation of the structures supplied by these nerves on blood pressure, respiration, and muscular activity. Definite reflex responses would indicate the presence of sensory fibers in the structures stimulated.

METHODS AND RESULTS

The distribution of the nerves was determined by dissections of newborn and adult cadavera, and by a detailed study of serial sections of human foetuses. Two human foetuses, sixty-one and 150 millimeters, crown-to-rump length, respectively, were obtained and were fixed almost immediately in Bouin's fluid. The lower portions of the trunks were doubly embedded in nitrocellulose and paraffin, were serially sectioned at ten micra, were stained with strong silver protein solution (Bodian's method), and were counterstained by means of a modification of Masson's method. Nerve fibers were sharply stained, and even the smallest ramifications could be seen. An additional three-month foetus (sixty millimeters, crown to rump), fixed in formalin, was serially sectioned and was stained by means of the Mallory azan method. Nerve trunks showed up well, but very tiny fascicles were difficult to follow.

Blood pressure and respiration were recorded and electromyograms were made in decerebrate cats during electrical and mechanical stimulation of the deep lumbosacral structures. Ten cats were used. Respiration was recorded by means of strain gauges which were mounted on a metal strip resting on the chest. As the strip bent with the movements of the chest, the gauges were deformed; the resulting changes in current flow were amplified and were fed into an inkwriter. Blood pressure was recorded by a strain-gauge manometer connected through a sodium citrate column to the common carotid artery. This method recorded absolute systolic and diastolic pressures; again the changes were recorded with an inkwriter. Needle electrodes in dorsal and hamstring muscles picked up electrical activity which was also recorded with the inkwriter.

GROSS ANATOMY

One newborn and two adult cadavera were dissected, and the course and the distribution of the lumbosacral posterior rami and the sinu-vertebral nerves were determined. Microscopic sections were made of many of the nerves and their branches. The sections were stained by means of a modification of Masson's method.

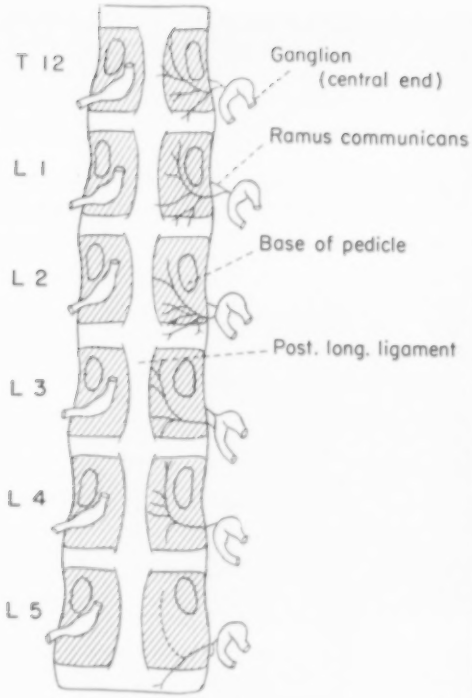

FIG. 1

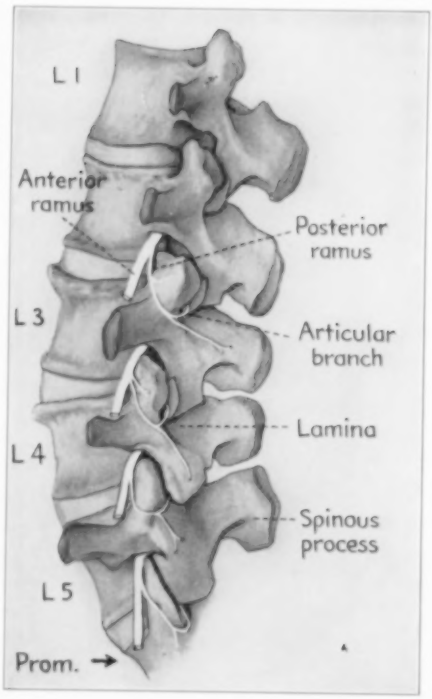

FIG. 2

Fig. 1: Diagrammatic representation of a dissection of sinu-vertebral nerves. The neural arches were removed down to the bases of the pedicles. The ganglia on the right side were turned laterally so as to show the origin of the nerves more effectively. The nerves on the left side were dissected but are not shown. Note that at the twelfth thoracic, the first lumbar, and the fifth lumbar vertebrae, the sinu-vertebral nerve arose from the ramus communicans, while at the second and third lumbar vertebrae it arose separately from the spinal nerve. The branches of the sinu-vertebral nerve were extremely small, broke easily, and are shown in the drawing up to the point where they ordinarily broke. Their distribution is, of course, more extensive than can be shown by dissection. The ascending branch of fifth lumbar nerve (dotted line) broke and could not be dissected as extensively as the others.

Fig. 2: Diagrammatic representation of an oblique view of a dissection of posterior rami designed to show their downward course and their medial branches next to the articular process. A small twig arises from each medial branch and courses upward to enter the capsule of the intervertebral joint. The course of the lateral branches of the posterior rami is not shown nor are the medial branches continued to their terminations.

Sinu-Vertebral Nerve (Ramus Meningeus, B.N.A.)

The nerves were exposed by means of a technique similar to that used by Luschka. After the excision of the dorsal muscles, the neural arches of the lumbar vertebrae were removed down to the bases of the pedicles. The spinal nerves were sectioned at the point where they left the dura mater and were retracted posterolaterally so as to expose their anterior aspects. The tissues of the anterior part of the spinal canal were carefully searched for nerve filaments. These were then traced back to their origin. The dura mater and contents were removed, and the ramifications of the filaments were dissected more completely.

Figure 1 is a diagram based on one of the dissections and shows the distribution of the sinu-vertebral nerves arising from the twelfth thoracic to the fifth lumbar spinal nerves. Each nerve either arises from its spinal nerve near the ramus communicans or with the ramus. (In the dissections a nerve was sometimes not found on one side at a particular level, probably because of its small size.) Each nerve, on entering the spinal canal, curves upward around the base of the pedicle and proceeds toward the mid-line of the posterior longitudinal ligament. During this course, filaments are given to the ligament, periosteum,

blood vessels of the epidural space, and dura mater. (The filaments were small and, in dissection, often broke near their termination, so that it was not possible to tell whether any entered the annulus fibrosus, or whether any crossed the disc above or below to anastomose with branches of other sinu-vertebral nerves. It was for this reason that the distribution of these nerves was studied in foetal material. We did not find in gross or microscopic material any nerves having only a downward course.)

Microscopic sections of sinu-vertebral nerves obtained by gross dissection showed many myelinated fibers, most of them quite small but some were more than ten micra in diameter (Fig. 3).

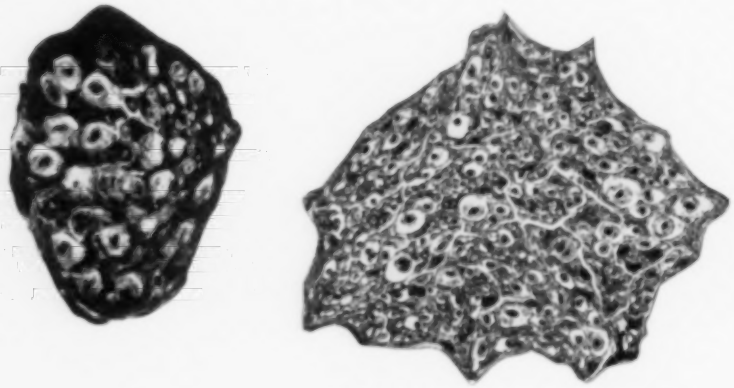

FIG. 3

Cross-section of articular twig (left) at approximately $\times 420$, and of sinu-vertebral nerve (right) at approximately $\times 450$, obtained from a dissection of the lumbar region and stained for myelinated fibers. The photographs were so trimmed as to remove the epineurium. Shrinkage is marked in the nerve as a whole and in the individual fibers. Nevertheless the range in fiber size is clearly evident. Myelin is light staining and the centrally placed axis cylinders are darker staining.

Posterior Rami

An anterolateral approach to the lumbosacral region was used. Beginning at about the twelfth thoracic vertebra, the psoas major muscle was removed, until the spinal nerves and their ganglia were reached. The posterior rami were then located and were dissected out.

The posterior rami pass backward through the connective tissue, uniting transverse processes (intratransverse ligaments), and almost immediately divide into medial and lateral branches. Each medial branch descends, posterior to the transverse process of the vertebra below, lying in a groove formed by the junction of the transverse process and the superior articular process. At the inferior margin of the superior process there is a small notch, bridged by connective tissue through which the nerve passes, where it gives a small twig to the inferior part of the articular capsule. Figure 2 illustrates diagrammatically the course of the medial branches with their articular twigs. The medial branch continues inferiorly, ramifying in the dorsal muscles and anastomosing with nerves from other levels. It was noted, especially from microscopic studies, that the medial branch lies next to the lamina and follows the inferior border of the spinous process posteriorly almost to the mid-line. The caudal course and free anastomoses of these nerves with branches of the segments above and below corroborate the findings reported in detail by Johnston.

The articular twigs are extremely small; it was, thus, sometimes difficult to be sure that they actually were nerves. But in most instances, microscopic sections revealed myelinated nerve fibers of various sizes, some larger than ten micra in diameter (Fig. 3).

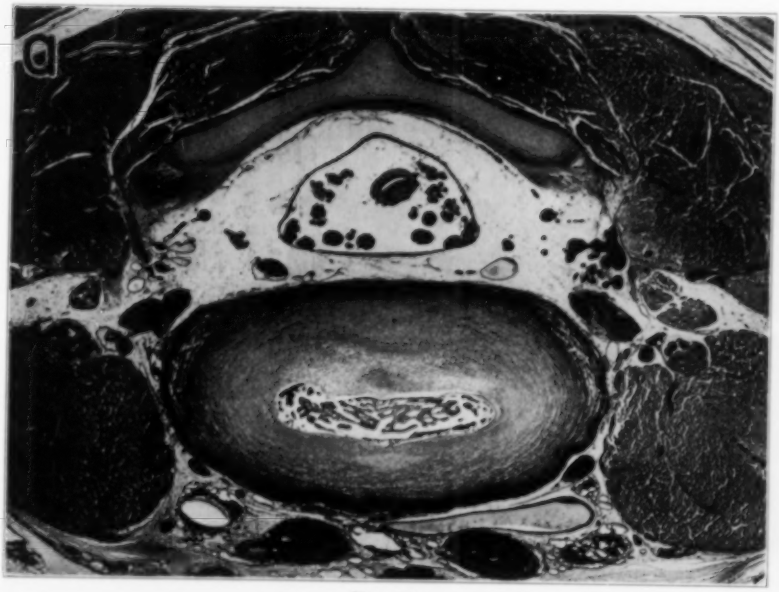

FIG. 4-A

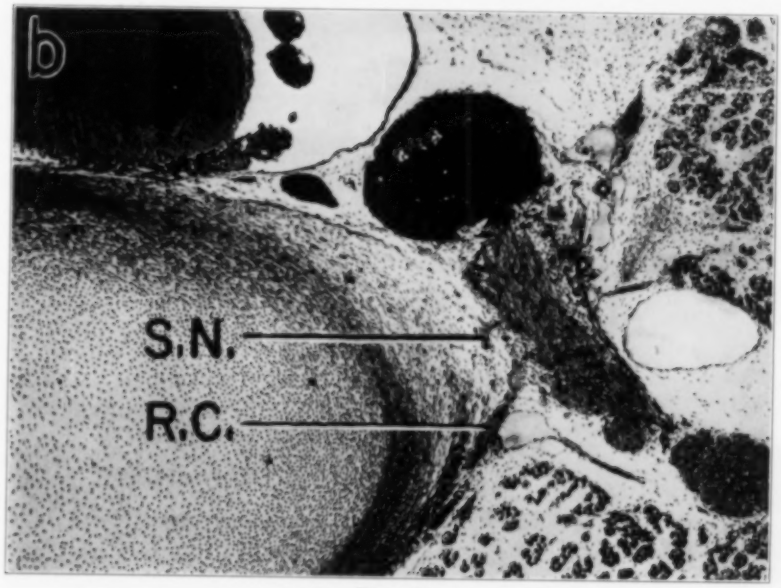

FIG. 4-B

Figs. 4-A to 4-G: A series of photomicrographs illustrating the sinu-vertebral nerve in human foetal material. Fig. 4-B is from a sixty-one-millimeter (twelve weeks) foetus, the rest are from a 150-millimeter (four and a half months) foetus. Magnifications are approximate.

Fig. 4-A: A transverse section through the fifth lumbar intervertebral disc, showing the nucleus pulposus, the annulus fibrosus, the ligaments, the spinous process, and the spinal nerves (× 5).

Fig. 4-B: Nerve and ganglion of the fourth lumbar spinal nerve. The sinu-vertebral nerve (S.N.), just arising from the spinal nerve, and the ramus communicans (R.C.), joining the fourth lumbar spinal nerve, are shown (× 36).

FOETAL ANATOMY

The advantage of using foetal material is that muscles, ligaments, nerves, and vessels are differentiated and are arranged just as they are in the adult, yet the foetus is small

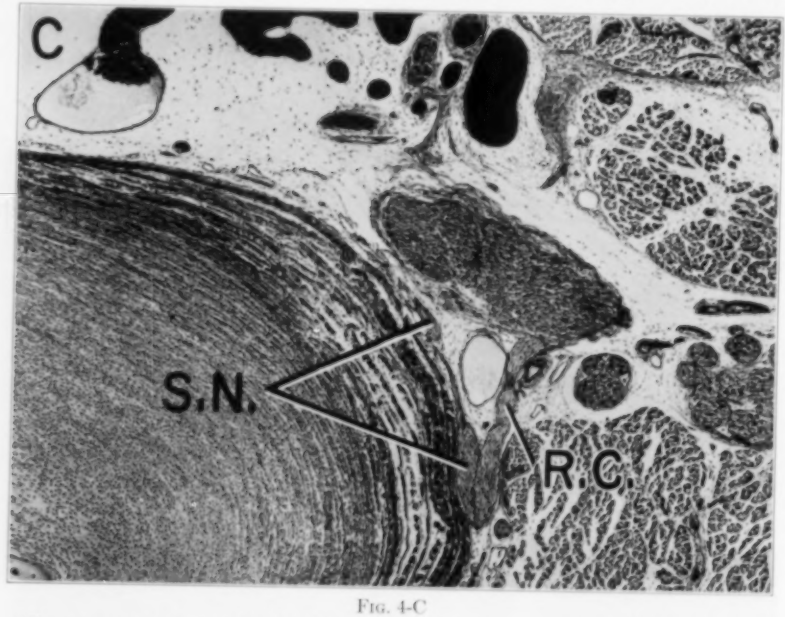

FIG. 4-C

The sinu-vertebral nerve (S.N.) arising from the ramus communicans (R.C.) to the fourth lumbar spinal nerve is shown (× 18).

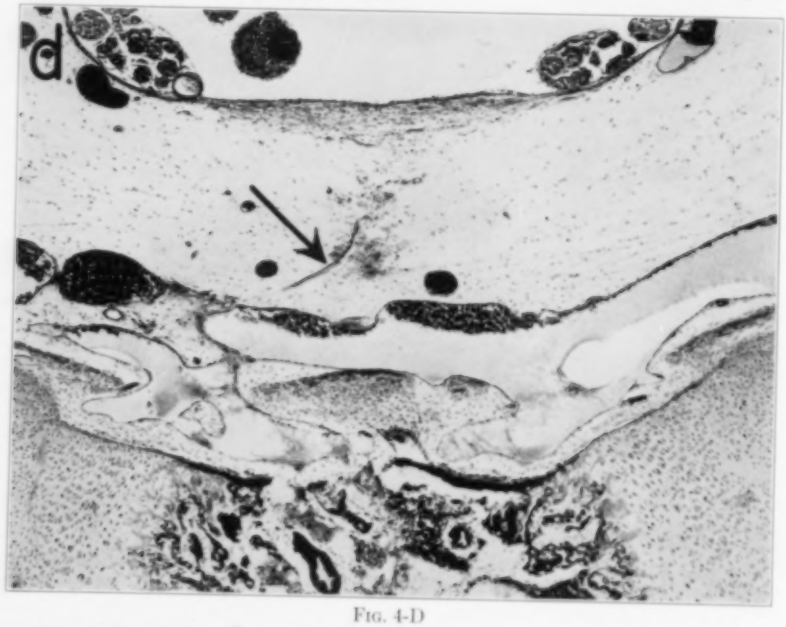

FIG. 4-D

Arrow indicates a branch of sinu-vertebral nerve to dura mater (upper). Vertebra below is ossifying (× 25).

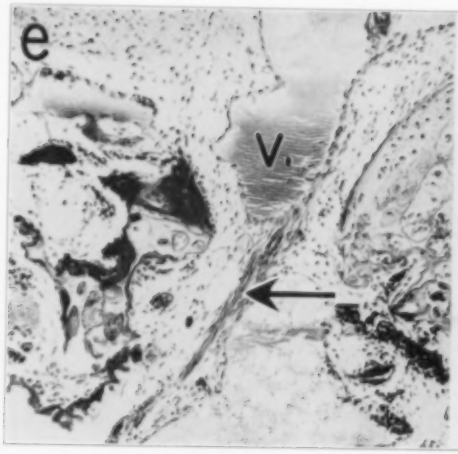

FIG. 4-E

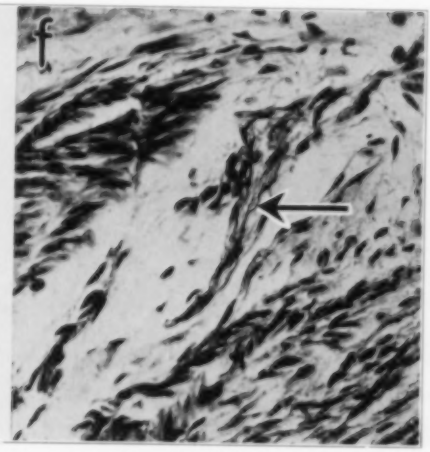

FIG. 4-F

Fig. 4-E: Arrow indicates nerve bundle from sinu-vertebral nerve accompanying small vein (V) in area of ossification of the fifth lumbar vertebrae (× 39).

Fig. 4-F: Arrow indicates one of several nerve fibers lying in the posterior longitudinal ligament over the fourth lumbar disc (× 163).

Fig. 4-G: Arrow indicates one of several nerve fibers in region near that shown in Figure 4-F (× 123).

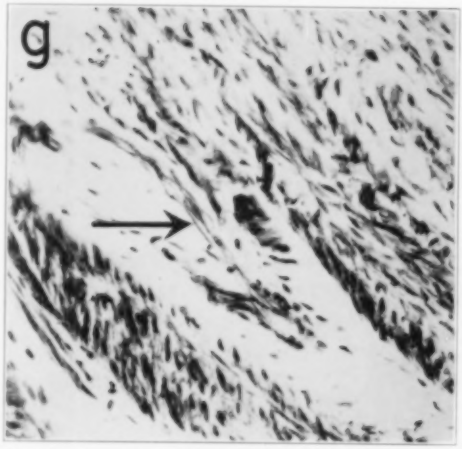

FIG. 4-G

enough to be sectioned serially (Fig. 4-A). Nerve trunks are relatively large, but nerve endings are poorly developed. Complex endings, such as Pacini's corpuscles, are not found until later in the prenatal period. What can be determined, therefore, are the pattern of distribution and the area of supply of any nerve.

Sinu-Vertebral Nerve (Ramus Meningeus)

The sections studied included the fourth and fifth lumbar roots and nerves and first sacral roots and nerves and the lumbosacral plexus. Sinu-vertebral nerves were found bilaterally, arising from each of the spinal nerves. As they do in adult cadavera, the sinu-vertebral nerves arise either directly from the spinal nerve just distal to the ganglion (Fig. 4-B), or else they arise jointly with the ramus communicans (Figs. 4-C and 5-A). It is rare to find but a single nerve. At each level, there are often several filaments, quite close together. It is possible that these filaments would later be bound together by connective tissue to form the sinu-vertebral nerve of the adult.

Some filaments ascend toward the disc above, while others descend past the disc below. Branches from each level anastomose with branches of the nerve above and below. In one instance, an anastomosis across the mid-line with the nerve of the opposite side was seen. The filaments were quite small, and the sections had to be studied repeatedly in order to trace their distribution accurately. Nerve fibers were traced to dura mater (Fig. 4-D), many were seen in the adventitia of blood vessels, and a number were followed into the posterior longitudinal ligament (Figs. 4-F and 4-G) and to the margin of what we considered to be the annulus fibrosus. No fibers were seen within the annulus. A num-

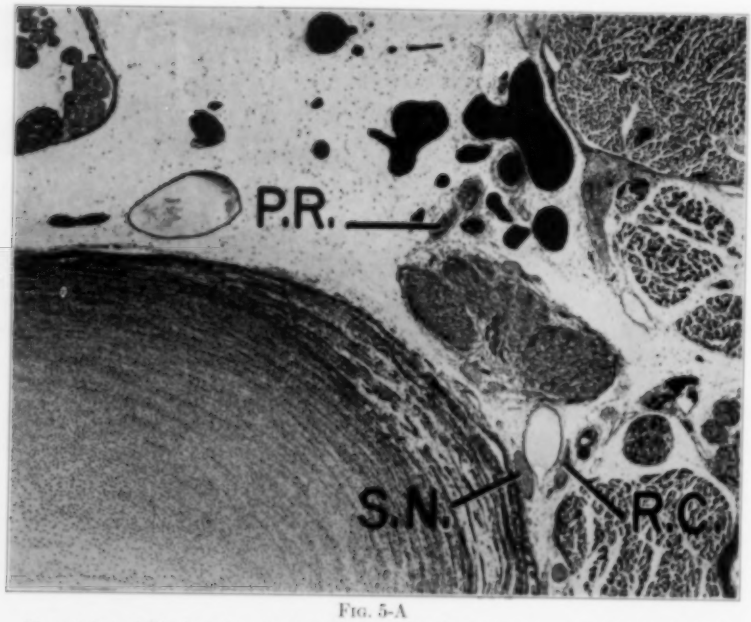

FIG. 5-A

Figs. 5-A to 5-F: A series of photomicrographs illustrating posterior rami, from the same 150-millimeter foetus. Magnifications are approximate.

Fig. 5-A: Fourth lumbar posterior ramus (P.R.) and anterior ramus. Ramus communicans (R.C.) and sinu-vertebral nerve (S.N.). The latter, having arisen from the ramus communicans, is coursing back into the spinal canal (× 18).

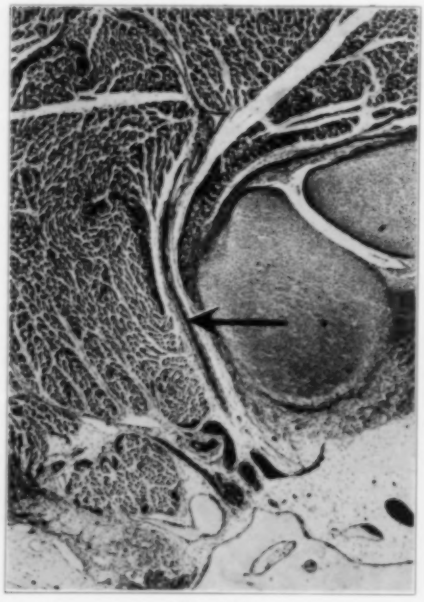

FIG. 5-B

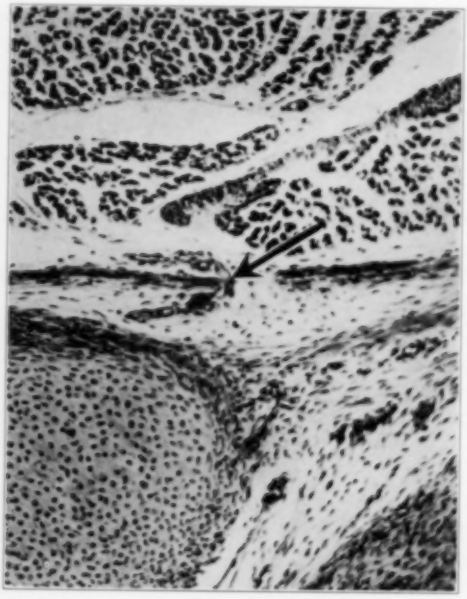

FIG. 5-C

Fig. 5-B: Arrow indicates medial branch of posterior ramus coursing next to an articular process. Note cavity in joint (× 18).

Fig. 5-C: Arrow indicates one of a few fibers traversing fibrous bundle into joint. Cartilage of the process is seen at lower left (× 80).

ber of filaments accompanied blood vessels into neural arches and vertebral bodies (Fig. 4-E). Our material definitely showed both a sympathetic and a spinal component for these nerves, and our findings with regard to distribution are therefore similar to those of Luschka. We made no attempt to study the innervation of the anterior longitudinal ligament, where nerve fibers have been reported by Jung and Brunschwig.

FIG. 5-D

Arrow indicates medial branch of posterior ramus continuing toward spinous process (S.P.) and interspinous ligament (× 18).

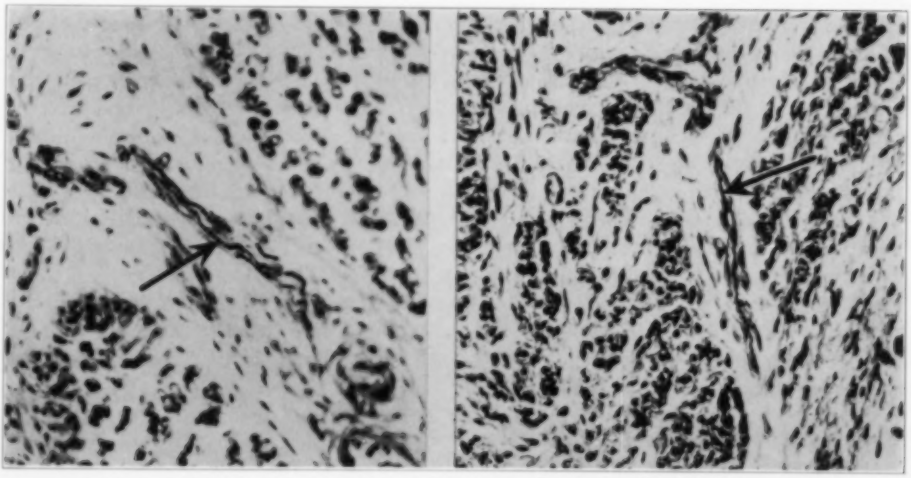

FIG. 5-E FIG. 5-F

Fig. 5-E: Arrow indicates several good-sized fibers approaching the interspinous ligament between the fifth lumbar and first sacral spinous processes (× 150).

Fig. 5-F: Nerve fibers (arrow) in the interspinous ligament between the fifth lumbar and first sacral spinous processes (× 150).

Posterior Rami

The course and distribution of these divisions were similar to what was found in the adult by dissection (Figs. 5-A to 5-F). In the three-month specimens, however, it was difficult to be sure that nerve fibers actually entered the capsules of the intervertebral joints. In the four-and-a-half-month specimen, small but definite twigs were found entering the inferior part of the joint. These could not be traced deeply into the joint, but were confined to the outer part of the capsule or to the adjacent periosteum (Fig. 5-C). We found no branches from the sinu-vertebral nerves to the intervertebral joints.

Fibers were also traced from spinal nerves directly to the adventitia of the blood vessels supplying the joints. The nature of these fibers could not be established with certainty, but many were lightly stained, as were the sympathetic fibers elsewhere. They may represent, therefore, a sympathetic contribution to articular vessels not coursing in an articular nerve. Some of these fibers could, of course, be sensory, but there was no way of being sure of this.

The medial branch of the posterior ramus continues to descend, lying close to the lamina (Fig. 5-D) and anastomoses during its course with medial branches above and below. Terminal filaments reach interspinous ligaments (Figs. 5-E and 5-F). Because of the descending course of these nerves, interspinous ligaments are supplied by fibers from the segment above. The ligament between the fifth lumbar and the first sacral vertebrae receives its main supply from the medial branch of the posterior ramus of the fourth lumbar nerve. It is entirely possible that additional segments may contribute, because of intersegmental anastomoses, but it was not possible to determine this precisely in the present study.

EXPERIMENTAL STUDIES

We had hoped to use Primate material, but one experiment with a monkey (*Macaca mulatta*) proved this to be impractical. When the ether anaesthesia was lightened to a point where reflexes occurred, struggling and widespread responses to stimuli masked any specific responses. A change to sodium pentothal anaesthesia appeared to block any significant changes. On the other hand, a cat decerebrated by transection at the mid-brain breathes regularly, is in a state of analgesia, and maintains blood pressure at a good level. The muscle rigidity which ensues may mask certain reflex muscular responses. However, if the spinal cord of such an animal is transected in the thoracic region, the rigidity disappears below this level, and the flexor muscles thereafter show marked reflex activity. Spinal shock lasts but a short time in the cat as compared with that in monkey and other Primates. While the results in the cat are not necessarily applicable to Primates, they may nevertheless show an organization of spinal connections which could be significant.

In not all decerebrated animals were the cords transected because this naturally prevents any reflex effect on brain stem centers. Transection itself usually causes a fall in blood pressure because the descending sympathetic pathways are interrupted.

Mechanical stimuli consisted in crushing joints, fascia, ligaments, muscle, and skin with a forceps. Hypertonic saline injected into these tissues served as another stimulus. In a few experiments, the posterior rami were stimulated electrically with strong repetitive shocks.

Blood Pressure and Respiration

In response to both mechanical and electrical stimulation of any of the structures mentioned, there was often an inspiratory shift, as if the animal were gasping, and, sometimes, a mild hyperpnoea. Blood-pressure changes were not marked. There was often a rise in both systolic and diastolic pressure (Fig. 6). Occasionally there was no change and sometimes the pressures dropped.

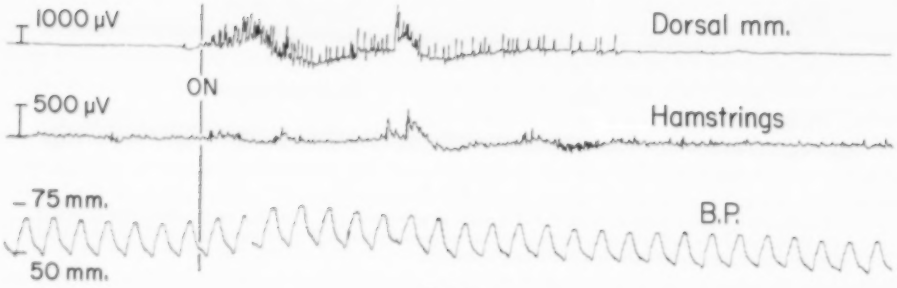

FIG. 6

Electromyographic records from cat T8, with cord transected. Reflex responses to mild pinch of upper lumbar intervertebral joint are seen at left. Upper line: electromyographic record from left dorsal muscles showing reflex activity. Height of bar at left, 1,000 microvolts. Middle line shows minimal response in left hamstrings. Lower line, blood pressure (pulse pressure about twenty millimeters of mercury), shows a mild reflex rise. Movement artifacts are present in the electromyographic records. Paper speed, three centimeters per second.

Reflex Muscle Activity

Mechanical stimulation of any structure, whether it was joint, fascia, ligament, periosteum, or muscle, was followed by reflex spasm of the dorsal muscles, mainly ipsilaterally. Crushing of muscle, however, ordinarily seemed to be a less effective stimulus. Similar spasm was recorded from hamstrings, especially when the structures stimulated were in the sacral or the lower lumbar region (Figs. 7 and 8). Such spasm often continued for a while after stimulation was stopped. Hamstring spasm also appeared to be mainly ipsilateral. Other muscles, especially in the thigh and the abdominal wall, also responded reflexly, but no recordings were made from them. Lewis and Kellgren [19] had reported similar findings with regard to these trunk muscles in both cat and man following injection of hypertonic saline into interspinous ligaments.

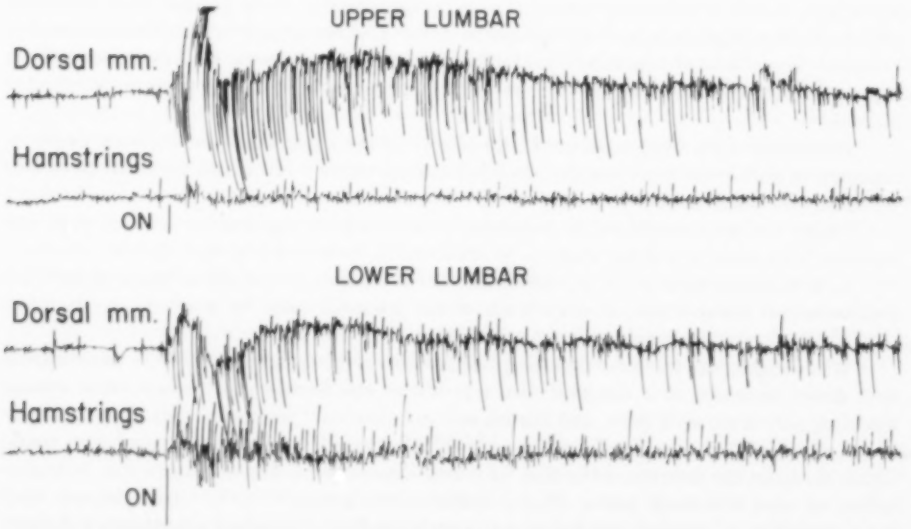

FIG. 7

Electromyographic records from cat T5, with cord transected. Upper two records show marked reflex response in the dorsal muscles, mild reflex response in the hamstrings, when dorsal muscles and lumbar fascia of upper lumbar region were crushed with forceps. Lower two records show marked hamstring response, as well as dorsal muscle response, following a similar stimulus in the lower lumbar region. Similar responses were obtained when joints and periosteum were stimulated. Paper speed, three centimeters per second.

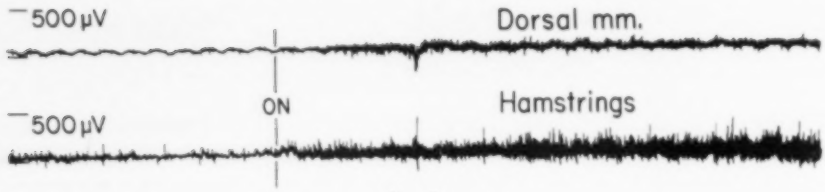

FIG. 8

Electromyographic records from cat T9, with cord transected. Ten per cent saline was injected into the base of the tail over the sacrum. Note long-continued reflex response in dorsal muscles and hamstrings. Paper speed, 0.6 centimeters per second.

DISCUSSION

The sinu-vertebral nerves and posterior rami are composed of both sympathetic and sensory fibers. Many of the latter are myelinated, and, in all probability, the smaller ones are pain fibers and the larger ones proprioceptive. It has been shown that proprioceptive impulses originating in the cervical joints of the cat are important in tonic neck reflexes [22], and Morin and Lepore have found sensory fibers in these joints in human foetuses. There is, however, no information on the proprioceptive functions of fibers from lumbar intervertebral joints, nor is anything known about the functions of such fibers in the sinu-vertebral nerves.

From the clinical standpoint, the important fibers in these nerves are those concerned with pain. The experiments reported here show that stimulation of these fibers produces reflex changes in blood pressure and respiration and causes widespread muscle spasm. Therefore, the sinu-vertebral nerves and posterior rami must contain pain fibers. The respiratory changes are those which can follow any painful stimulus and are, therefore, non-specific. The blood-pressure changes are likewise non-specific. The variations in such changes can be explained by the fact that in peripheral nerves there are small, slowly conducting fibers which have a reflex pressor effect, while depressor effects are mediated by larger, faster conducting fibers.[5] In our experiments, both groups were probably activated simultaneously, so that changes in either direction might result. The groups can, however, be activated separately in dealing with deep structures, and depressor effects after stimulation of sensory fibers from joints have been demonstrated in experimental animals.[6]

In animals with transected cords, no effects on the brain stem centers were possible. Changes in such cases were usually a mild rise of an already low blood pressure, probably secondary to reflex muscle activity.

There has been considerable discussion concerning the mechanism of back pain and sciatica. Two main problems seem to be involved in intervertebral-disc disease:

1. If a spinal root is not involved, is pain the result of the stimulation of just the sinu-vertebral nerve fibers, or may fibers of the posterior rami be involved in any way?

2. Can lower-extremity pain be referred?

With regard to the first question, a number of investigators [4, 20, 24, 33] have shown that direct pressure on a diseased disc reproduces the backache. Pressure on a normal disc does not cause such pain, and Hirsch and Schajowicz [10] suggested that the sensitivity of the diseased disc may be due to the growth of nerve fibers into the granulation tissue which occupies the fissures of the disc. It seems clear that backache may be due to stimulation of sinu-vertebral nerve fibers. Other investigators [17, 18, 19, 28] have shown that hypertonic saline injected into the dorsal muscles and the ligaments also causes a diffuse, poorly localized backache. Our own experiments indicate that stimulation of any deep structure of the lumbosacral region causes a non-specific, widespread muscle spasm. Thus, a painful stimulus to any deep structure can cause backache. Also, with disease of the intervertebral disc, it is apparent that painful stimuli may arise from many of these

structures simultaneously. Putti and Badgley, for example, have called particular attention to the role of the intervertebral joints in the pathogenesis of backache and sciatica. More recently Harris and Macnab published a very clear account of the structural changes which follow disease of the disc. They pointed out that with narrowing of the intervertebral space subluxation of the joints is common and that the tip of the inferior process impinges on the subjacent lamina and induces a bony reaction. Such degenerative changes must be a source of pain. Therefore, the backache accompanying disc disease may have multiple causes.

With regard to the second question, whether or not lower-extremity pain in such cases may be referred, some investigators, such as Falconer and his associates state that direct pressure on a diseased disc reproduces the backache but not the sciatica. Hirsch[8, 9] has shown that pressure changes in a disc caused by the injection of solutions can reproduce the patient's pain. Lindblom and Perey reproduced both sciatica and backache by injecting diseased discs with contrast medium; they prevented the pain by including a local anaesthetic with the injection solution. The latter finding is hard to explain unless one assumes that the anaesthetic diffused until it reached the spinal nerve or the anterior ramus, or both, and the sinu-vertebral nerve. These authors, and probably most other authors, apparently consider it unlikely that lower-extremity pain occurs without direct nerve-root pressure. However, pressure on a diseased disc in the operating room or on the x-ray table is not comparable to the effects of body weight and movement during activity. Because such pressure does not reproduce sciatica does not mean that a stimulus of sufficient intensity could not do so. There are both experimental and clinical evidence showing that lower-extremity pain can be referred in origin. Kellgren[17, 18] found that referred lower-extremity and abdominal pain follow injection of hypertonic saline into the dorsal muscles and the ligaments. Sinclair and his associates obtained similar results, although they differed with Kellgren over interpretative details. Under certain conditions, their subjects felt pain in the area of an anterior ramus when saline was injected into the area of a posterior ramus. More than anything else, their results indicate that the stimulus must reach a certain intensity before the pain is referred. Inman and Saunders[12, 13] likewise concluded from studies on human subjects that painful stimulation of the deep structures of the back could lead to referred pain. Steindler and Luck reported a series of patients in whom lower-extremity pain was relieved by procaine injection of the deep lumbar structures. Lewis and Kellgren demonstrated in cats and in man that stimulation of the deep structures of the low back causes not only pain but also reflex muscle spasm in the trunk. Our own experiments show that with low-lumbar stimulation reflex-muscle spasm occurs in the lower extremity, as well as in the dorsal muscles and in other trunk muscles.

It seems quite likely that lower-extremity pain may follow direct root pressure, but may also be referred, provided that the painful stimulus is strong enough or is caused by multiple factors. We would again emphasize the poor localization of pain associated with deep lesions of the lumbosacral area and the difficulty of localizing many of these lesions on the basis of the physical findings.

SUMMARY

The distribution of the lumbosacral posterior rami and the sinu-vertebral branches (ramus meningeus) of spinal nerves was determined by dissection of newborn and adult cadavera and by a detailed study of serial sections of human foetuses. In addition, blood pressure and respiration were recorded and electromyograms were made in decerebrate cats during electrical and mechanical stimulation of low-back structures.

The posterior rami, in addition to their cutaneous and muscular distribution, give sensory fibers to fascia, ligaments, periosteum, and intervertebral joints. Adjacent divisions overlap in their area of supply. Interspinous ligaments are supplied mainly by

branches from the next cranial level. Sinu-vertebral nerves supply posterior longitudinal ligament, dura mater, periosteum, and blood vessels, show intersegmental anastomoses, and contain sensory fibers.

Painful stimulation of joints and ligaments of the lumbosacral region in cats produces reflex spasm of dorsal and hamstring muscles, as well as non-specific changes in respiration and blood pressure.

It is suggested that clinically a painful stimulus to any deep structure in this region is poorly localized and can give rise to a common symptom complex which includes both low-back and leg pain.

NOTE: Since this paper was submitted for publication, a pertinent study, "The Nerve Supply of the Vertebral Column and Its Associated Structures in the Monkey", has been completed by D. P. Stilwell and will be published in The Anatomical Record in 1956. Stilwell used the methylene-blue technique and was able to determine the manner in which nerve fibers ended. He demonstrated that the gross distribution of these nerves in the monkey is similar to that described in this paper. He found overlap of adjacent segments, free nerve endings (presumably pain) in such structures as joint capsules, and posterior longitudinal ligament and proprioceptive endings in the capsules of the posterior joints.

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DISCUSSION

Dr. J. Vernon Luck, Los Angeles, California: This is an important contribution to our understanding of the lumbosacral region. There is need for such meticulous anatomical studies carefully correlated with clinical features.

As the authors have brought out, there is little in the literature to answer the question of specific allocations of pain in the low back. When we leave the root-impingement syndrome we find ourselves in areas of uncertainty. From 1935 to 1939, it was my privilege to work with Dr. Steindler on a similar, although less comprehensive, anatomical study of the lumbosacral region. We made a particular effort to identify the sources of radiating pain into the lower extremities; it was in this study that the classification into vertical units of the lumbosacral and sacro-iliac regions were discarded for the horizontal unit systems—particularly those represented by the posterior divisions. To this end, it was necessary to differentiate between the territory of the anterior and posterior primary divisions of the spinal nerves. The posterior division syndrome was described. As you know, it included those entities in the lumbar region involving tissues supplied by the posterior division sensory nerves. In the clinical aspect of our investigation the reflex sciatic radiation was identified. The trigger points of tenderness in the low back were injected with procaine hydrochloride. It was found, in the course of these injections, that the radiating pain into a lower extremity frequently could be reproduced and accentuated by the needle point as it probed into the soft tissues at the site of trigger-point tenderness. It was concluded that this was a reflex type of radiation rather than the conventional referred pain and that it passed from the posterior divisions across and radiated down the primary anterior division distribution. This reflex sciatic radiation was differentiated from the referred pain of root impingement by several characteristics. It was observed that the distal boundary of the distribution, that is, the distance distally which the radiating pain reached, depended upon the intensity of the pain stimuli. A moderate degree of reflex radiating pain may extend into the buttocks or thigh; in more severe degrees of radiation from the same focus in the soft tissues the pain would radiate farther, and even as far distally as the foot. There are no associated reflex or sensory changes but there frequently is a great deal of muscle spasm associated with these reflex radiations. The creation of the procaine test was based on the fact that, following the injection of the procaine, the radiating pain was suppressed together with the local pain, for the duration of the effect of the procaine, and further, the leg signs became negative. This was viewed as a positive test. As you well know, reflex radiations of this type are by no means limited to the lower extremities and lesions in the low back. We see similar reflex radiations from a lateral epicondylitis of the elbow where the radiating pain may go into the hand; upper-extremity reflex radiations may be dispatched from a sub-deltoid bursitis or calcific tendinitis. Similar observations on reflex radiations have been made by Kellgren and others through the use of saline injections into the various soft-tissue parts in the lumbar region. It is our belief that the use of the procaine test offers important possibilities in the further identification of sources of pain in low-back lesions. Our conviction regarding reflex radiations has been challenged in some quarters, but it is our belief that the concept is standing the test of time and has been further confirmed by Pedersen, Blunck, and Gardner.

Late Effects (Twenty-Five to Forty Years) of the Early Medical and Industrial Use of Radioactive Materials

Their Relation to the More Accurate Establishment of Maximum Permissible Amounts of Radioactive Elements in the Body

Part III *

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DISCUSSION

General Comments

It is evident from these studies that the clinical diagnosis and management of patients who have internally deposited radioactive materials is dependent upon the understanding of the radiobiology of the radioactive element in question. For example, it is known that radium and plutonium are deposited primarily in bone, while thorium is deposited in the liver, the spleen, and the bone marrow [20, 21]. When the principal sites of deposition are known, it is apparent that clinical changes are most likely to occur at these sites.

Other considerations in the management of patients with internally deposited radioactive elements with long physical and biological half-lives are as follows. Subclinical changes may alter the clinical course of an intercurrent disease process as a result of an undetected decrease in the function of one or more organs of the body. It has been shown in animals that one large dose of a radioactive element may affect the hematopoietic system primarily, while smaller doses of the same radioactive element given several times may cause the greatest damage to the kidneys [1]. Another observation from animal experimentation emphasizes that at least one generation should be studied before reliable maximum permissible levels are established. This is the observation that a reduction in life expectancy without gross symptoms has been the most significant finding following the administration of small amounts of radioactive elements [5]. The present number of cases is too small and follow-up studies have not been made long enough to determine if a similar effect is present in man.

One of the most complex problems in determining the biological effects of the heavy radioactive elements, such as radium, uranium, and thorium, is the long decay series in which a number of new radioactive elements are formed. For example, nine radioactive elements are formed in the decay of radium ^{226} to stable lead. Many of these daughter products have different physical, chemical, and biological properties.

Clinical Considerations

Any patient in the middle-age group or old-age group who has significant skeletal changes, dental changes, or tumors of the skeleton should be questioned as to previous radium administration or previous employment as a luminous-dial worker. Many of these patients do not remember receiving radium so that a negative history does not rule out this possibility. If there is enough radium to cause significant clinical changes, then its presence can be established by the various methods listed:

1. History of radium inhalation, ingestion, or administration;

* This is the last of three articles in a thoroughgoing analysis of the late effects of the early medical and industrial use of radioactive materials. The first appeared in the December 1955 issue of *The Journal* (pages 1169 to 1187); the second in the January 1956 issue of *The Journal* (pages 175–218). It is suggested, in order that the reader may gain the full significance of this report, that he read the first two parts.

2. Skeletal roentgenographic changes characteristic of radioactive-element deposition;

3. Determination of the radon in the expired air;

4. Radiochemical analysis of the excreta;

5. External measurement of the gamma-ray activity;

6. Radiochemical analysis of a bone biopsy specimen.

Usually there are characteristic roentgenographic changes if significant amounts of radium are present in the body. If the diagnosis cannot be established by methods 1 and 2, the most practical laboratory tests are methods 3 and 4. A twenty-four to forty-eight hour fecal specimen may be sent to a laboratory equipped to do the radiochemical analysis for radium content.

The management of these patients is primarily concerned with relief of symptoms, supportive measures, orthopaedic management when gross skeletal lesions occur, and vigilance in regard to the occurrence of malignant tumors. Once pain occurs, more and more analgesics will be required to control the patient's pain. Three patients had some temporary relief of pain following the use of ACTH and cortisone. Once anaemia develops it is usually refractory to therapy. A complete skeletal roentgenographic examination should be made in order that any disturbances might be compared with the base-line roentgenograms. Any persistent pain should be checked with a roentgenographic examination of the area involved. This is especially true in regard to the common sites of tumor formation (see Part II, Fig. 19). Biopsy should be done on any suspicious change. If a malignant tumor occurs in an area where surgical removal can be carried out, it should be done since it has been shown that removal of an extremity may be life-saving (Patient C.P., L-8).

A skeletal roentgenographic examination should be repeated about every one to three years *. This will gauge the progression of the disease and will give valuable information on the occurrence of the roentgenographic changes as a function of time.

Clinical Changes in Relation to the Estimated Amount of Radium in the Body

Two of the most important considerations in attempts to establish maximum permissible body burdens in human beings more accurately are as follows: the sampling of the patients evaluated from the population of individuals who have radioactive elements in their bodies and satisfactory control groups in the evaluation of the clinical findings. For example, fifteen of the twenty-eight luminous-dial workers (55 per cent) were discovered as a result of symptoms from radioactive-element deposition, whereas in only fifteen of the fifty patients given radium (30 per cent) was the diagnosis made from symptoms. It is readily apparent that erroneous conclusions could be drawn from the two groups as well as from the general clinical effects of the toxicity of radioactive elements based on the biased selection of only patients who have difficulties. The need for suitable control groups is illustrated by the following example. Eleven patients of the eighty (14 per cent of the series) had aseptic necrosis of the femoral head without a history of antecedent trauma. To evaluate accurately the relationship of the aseptic necrosis to the deposition of radioactive elements, accurate information on the frequency of aseptic necrosis of the femoral head in comparable control groups is necessary.

Hematological Findings

In 1925, Castle, Drinker, and Drinker reported the hematological findings of twenty-two luminous-dial workers. The erythrocyte count was below 4,000,000 in 6 per cent of these cases and above 6,000,000 in 19 per cent. The white-blood-cell count was below 7,000 in 27 per cent of the workers. Abnormal erythrocytes occurred in 36 per cent of the series.

* A record should be made of the amount of radiation received and great care should be taken to keep exposure to a minimum.

There was an increase in lymphocytes and monocytes and decrease in the polymorphonuclear neutrophils found on differential examination.

In 1932, the Public Health Service made a study of 196 employees of luminous-dial-painting plants. Anisocytosis was found in 11 per cent of these people and poikilocytosis in 8 per cent. The average erythrocyte count in the Public Health Service series was 4,300,000 as compared with an average of 4,500,000 in a series of thirty-one control patients [19].

Hematological data were available on four patients who died. Two of these patients died from malignant tumors—patient M. K. (R-24) and patient F. W. (B-7). Patient A. DeR. (R-44) died from aplastic anaemia and patient M. L. (L-27) died from secondary infection and debilitation (see Part II, Table IX).

The marked pancytopenia that occurred in Martland's cases [16] had not occurred in the patients evaluated in 1951. A short time before death, there were usually about 3,000,000 erythrocytes per cubic millimeter and 10 grams of hemoglobin per 100 cubic centimeters. No hemorrhagic manifestations occurred in these patients. Some of Martland's cases had less than 1,000,000 erythrocytes and less than 1,000 leukocytes per cubic millimeter shortly before death. He considered the anaemia which developed in his patients to be of a regenerative type resembling pernicious anaemia, and he described the hematological changes in the following way: "The blood in this case showed a profound anemia, characterized by a large cell anisocytosis, by the presence of megaloblasts and by a marked leukopenia. There was not, however, a hyperbilirubinemia, and the van den Bergh tests were negative. The anemia is, therefore, not a hemolytic anemia. It is not an aplastic anemia, since there is marked embryonal blood formation. The fault lies in a long continued irritation of the hematopoietic system, the hemolytic or reticuloendothelial system being unaffected. There is a stage of stimulation followed later by sudden exhaustion of the erythroblastic and leukoblastic centers with the production of a rapid, fatal anemia with leukopenia, which fails to be influenced by any form of treatment." Red regenerative marrow was present in the femora of some of these patients [16].

These changes in the hematopoietic system are similar to those seen in the acute radiation syndrome [11]. Most patients who lived less than six weeks following external radiation had hypoplastic marrow. Some patients who died at four to five months after exposure had diffuse myeloid hyperplasia which involved even such long bones as the femur. Occasionally the marrow appeared pink and gelatinous [11,12].

The bone marrow of patient M. K. (R-24) was studied in 1948, eighteen years after radium administration. It was reported to be distinctly overactive. There was moderate erythroblastic activity with an excessive number of cells in mitosis without a shift to the left. The remainder of the cells were normal. The erythrocyte count was 5,300,000 per cubic millimeter and hemoglobin was 12 grams per 100 cubic centimeters at this time. The erythrocyte count was 3,000,000 per cubic millimeter and hemoglobin was 9 grams per 100 cubic centimeters shortly before death in 1951. Small pink areas of hyperplasia were found in the femur and tibia at autopsy. Sternal marrow from Mrs. K. B. (R-43) revealed extremely atrophic marrow shortly before her death in 1947. There were only small areas of erythropoiesis and the remainder of the marrow was composed principally of fat cells. No evidence of excess destruction, serious fat atrophy, or fibrosis was observed. The hemoglobin at this time was 12.6 grams per 100 cubic centimeters and the erythrocyte count was 3,890,000 per cubic millimeter.

Patients who have over one microgram of retained radium are more likely to have anisocytosis, poikilocytosis, and hypochromia of the erythrocytes than those having under one microgram (see Part II, Table XII). However, significant hematological changes usually do not occur until late in the course of the disease.

In view of this additional information, it appears that little qualitative difference exists in the hematological response to internal or external radiation. If an individual had

received large enough amounts of radioactive substances internally, hematological changes occurred which were similar to the hematological changes following exposure to large amounts of external radiation. In individuals who had received smaller amounts of either internal or external radiation, the hematological response at any given time was varied. The type and number of cells in the circulation at any specific time is the result of the natural survival of the cells and the balance between their radiosensitivity and their ability to recover from injury [22].

The red regenerative marrow that Martland described was in all probability an abnormal attempt of the hematopoietic system at increased production as a result of damage. Martland's term leukopenia anaemia of regenerative type which was used to describe the hematological changes in the luminous-dial workers does not seem to be appropriate. The anaemia that develops in these patients and the patients who had received radium would be more suitably placed in the category of primary refractory anaemia in which either a hyperplastic or hypoplastic (aplastic anaemia) bone marrow may be found [22].

Symptoms

The time between the deposition of the radioactive elements and the onset of the first symptoms was analyzed in order to see whether any correlation could be made between this period and increasing amounts of retained radium. Twenty-one of the twenty-five luminous-dial workers had symptoms referable to radioactive-element deposition and twenty-five of the fifty patients who had received radium had symptoms that could reasonably be attributed to radioactive-element deposition.

The luminous-dial workers and patients who had received radium were divided into two groups. The first ten patients of the luminous-dial workers who had symptoms and had between 0.1 to 1.5 micrograms of retained radium were compared with the eleven luminous-dial workers having between 1.6 and eighteen micrograms of retained radium (see Part II, Table V). The average time before symptoms occurred in the first group was sixteen years and in the second group was fifteen years. The twenty-five patients who had received radium who had symptoms referable to the deposition of radioactive elements were divided into two groups (see Part II, Table IV). The first twelve patients had between 0.7 and 4.2 micrograms of retained radium, the other thirteen patients had between five and twenty-two micrograms. The average time before symptoms occurred in the first group was seventeen years and in the second group was sixteen years. There was no increase in the time interval before symptoms occurred in the first group, even though there was from about ten to 100 times less radium in the body. It should be noted that the period of latency before the onset of symptoms that could reasonably be attributed to the deposition of radioactive elements varied from one to thirty-two years.

Since no relation between increasing amounts of radium and the time before symptoms occurred from deposition of radioactive elements was found, the frequency of involvement of the femur was examined to see if some correlation could be made with the retained radium. Nine patients who had received radium (Patients 13, 28, 30, 42, 43, 44 *, 47, 48, and 50; Part II, Table III) had aseptic necrosis of the head of one or both femora as did luminous-dial workers (Patients 21 and 28; Part II, Table IV).

It is well known that aseptic necrosis of the femoral head usually occurs as a result of trauma or following fractures of the neck of the femur. It is also true that aseptic necrosis does occur in which the etiology cannot definitely be established. In these cases, it is considered that circulatory disturbances are the primary cause of the necrosis. The cause of the disturbance is poorly understood; it may be from gradual occlusion or from trauma [18]. Unfortunately there is little information concerning the incidence of unexplained aseptic necrosis of the femoral head. Estimates of the occurrence of aseptic necrosis

* This patient had aseptic necrosis of the weight-bearing roof of the acetabulum.

of the femoral head from all causes approximated one in 200 in an orthopaedic practice [9].

The 14 per cent incidence of aseptic necrosis of the femoral head in these patients seems unusually high in the absence of a history of antecedent trauma or fracture. It is interesting to note that all of the lesions occurred in patients having 0.7 microgram or more of radium in their bodies. The average time from the deposition of the radioactive elements until symptoms referable to the femoral head occurred was fifteen years, approximately the same as that for symptoms in all other parts of the skeleton. The time of onset varied from nine to twenty-two years.

Almost all of the fractures occurred in the shaft of the femur. Some of the patients fractured both femora, as well as sustaining refracture one or more times. Fractures following such minimal trauma as pressure of the foot on the floor of the car emphasize the fragility of the skeleton that may result from the deposition of radioactive elements.

Fractures of the femur occurred in four of the luminous-dial workers (see Part II, Table V, Patients 12, 14, 17, 27) and in only one patient who had received radium (see Part II, Table IV, Patient 35). Again it should be noted that all of the fractures occurred in patients having 0.9 microgram or more of retained radium.

It is evident that reliable data on the frequency of aseptic necrosis of the femoral head and of the bones of the feet and of collapse of vertebrae in various age groups are necessary for the more accurate clinical evaluation of the effects of radioactive elements deposited in the skeleton.

Tumor Formation

The following observations have been made in regard to the development of malignant tumors in relation to the retained radium. The fifteen malignant tumors that developed in the seventy-eight patients recently evaluated (1951) were found in individuals having between 0.5 to ten micrograms of retained radium present in their bodies. Since patients who had received radium and luminous-dial workers were found to be equally distributed throughout this range, little can be said about differences in the development of malignant tumors in luminous-dial workers and patients who had been given radium with comparable amounts of radium in the body (see Part II; Fig. 19). Eleven of these patients (about 14 per cent of the series) had sarcomata arising in bone. Carcinomata developed in the nasopharyngeal region in three of the luminous-dial workers, and one luminous-dial worker had a swelling of the mandible that was considered to be a giant-cell tumor; however, this was not confirmed histologically [2]. The development of the malignant tumors in the nasophyaryngeal region of the luminous-dial workers is suggestive that there may be some relationship in the occurrence of tumors to the route of intake of the radioactive element. One patient given radium intravenously, however, has been reported to have a malignant tumor in this region.

Brues, Lisco, and Finkel found that following the administration of the bone-seeking radioactive element, as compared to mice, the predominant resulting malignant tumor was sarcoma. However, other tumors of endothelial and mesenchymal origin did develop in the animals. It is possible that the nasopharyngeal tumors in the luminous-dial workers are related to the mode of deposition of radioactive element. It is also possible that the route of intake and the difference in the effects of mesothorium and its daughter radioactive elements, as compared with the effects of radium and its daughter radioactive elements, may have some relation to the development of carcinomata.

It is interesting to note that all of the sarcomata developed at the ends of the bones. Another interesting clinical observation is that the tumors did not develop in bones which most commonly were the sites of aseptic necrosis, with the exception of one fibrosarcoma of the tarsal navicular in the foot of patient M. K. (R-24).

The 14 per cent frequency of bone tumors is unusually high in these patients. This is more striking when one considers that bone sarcomata usually occur in young people

in the second decade of life. Bone tumors developed in these patients in the fourth to seventh decade (average age of onset, fifty years). Sarcoma developed in one patient at seventy-four years. Although no direct comparison can be made, the incidence of bone tumors in the general population in this country is one in 100,000 and in Great Britain one in 75,000.[8]

If only the sarcomata of bone are considered in the luminous-dial workers and the patients who had been given radium the frequency in each group is about the same. If all of the tumors are included, the frequency in the luminous-dial workers is about twice the frequency in the patients who had been given radium.

The following factors may account for the higher frequency of tumors in the luminous-dial workers. The age at the time of deposition was seventeen years, as opposed to thirty-nine years for the radium patients, and the more biased selection from patients having symptoms from the deposition of radioactive elements is 55 per cent contrasted with 30 per cent. The route of intake and the radioactive elements deposited have been given considerable attention previously. In addition, the rate of ingestion may also be related. The luminous-dial workers ingested or inhaled radioactive elements daily for over a period of months to years. The patients given radium medically usually received radium at weekly or biweekly intervals for weeks to months. Little differentiation can be made in regard to the frequency of malignant tumors in the luminous-dial workers and patients who had been given radium from this small number of cases. However, these differences are important considerations in the event that sufficient clinical data become available for contrasting the frequency of development of malignant tumors in these two groups of patients.

There is rather general agreement that malignant tumors develop in or around areas of proliferating fibrous connective tissue and atypical osseous-tissue formation. Martland considered that the cellular stage of "radiation osteitis" was responsible for the development of the sarcoma [17]. These changes are similar to those found by Bloom and Bloom following the deposition of radioactive elements in animals in which they noted atypical osseous tissue and proliferation of fibrous tissue [3,4]. Evans and his associates considered that sarcomata which developed in rats probably arose in places where these abnormal attempts at bone formation were taking place. Bloom and Bloom [4] in their studies of plutonium and radium in mice found early changes of an atypical proliferative nature in one specimen three months after the administration of radium and seven months after the administration of plutonium. They considered that these changes could represent early sarcoma or a predisposing state.

Martland [17] considered that tumor production resulted from the direct effects of radiation. Relatively little radioactivity was found in or around the atypical osseous tissue in autoradiographs made from specimens from the patients who had been given radium and the luminous-dial workers [14]. Similar autoradiographic findings were observed in rats in which malignant tumors developed following the administration of plutonium [13].

It is possible that the tumor arises in the atypical osseous tissue which is relatively free of radioactivity. However, the possibility of radiation producing genetic changes in the preceding generations of cells in the atypical tissue cannot be excluded.

The wide dissemination of sarcoma in patients I. D. and Mrs. A. DeR. is suggestive that multiple tumor sites occur in man. Brues, Lisco, and Finkel found that multiple tumors occurred more frequently in animals as the dosage increased.

Eight luminous-dial workers in whom malignant tumors were reported to have developed in 1931 [17] were contrasted with the thirteen patients who were found to have malignant tumors in the 1951 Boston and Chicago investigations. There is suggestive evidence that an inverse relationship may exist between the amount of retained radium and the length of time before the malignant tumors develop (see Part II, Table X). It is interesting to note that the period between the time of deposition and the development of

TABLE I

AGE AND SEX DISTRIBUTION OF THIRTY-TWO PATIENTS HAVING BETWEEN 0.5 AND 14 MICROGRAMS OF RADIUM PRESENT IN THEIR BODIES ON AN AVERAGE OF TWENTY-ONE YEARS AFTER DEPOSITION

	Group I (0.5 to 1 Microgram)	Group II (1 to 2 Micrograms)	Group III (2 to 14 Micrograms)	Total
Sex				
Male	4	2	5	11
Female	11	6	4	21
	15	8	9	32
Age				
30–40	1	0	0	1
40–50	9	4	2	15
50–60	3	3	2	8
60–70	0	0	3	3
70–80	2	1	2	5
Average age (years)	49	51.9	60.9	
Average time (years) since administration	20.3	22.2	22	

symptoms is about three times as long in the patients studied in the 1951 series as that in patients in the 1931 series. The average radium content, however, is eight times less in the 1951 series. A similar inverse relationship between the size of the dose and the "latent period" was seen in animals given strontium [6]. Brues considered that the latent period appeared to vary approximately with the inverse of the square root of the dose.

The latent period based on the onset of symptoms at the site of tumor origin was about nine years in the luminous-dial workers evaluated in 1931. The latent period for the luminous-dial workers and patients given radium evaluated in 1951 was about twenty-five years.

These data bring up two interesting points:

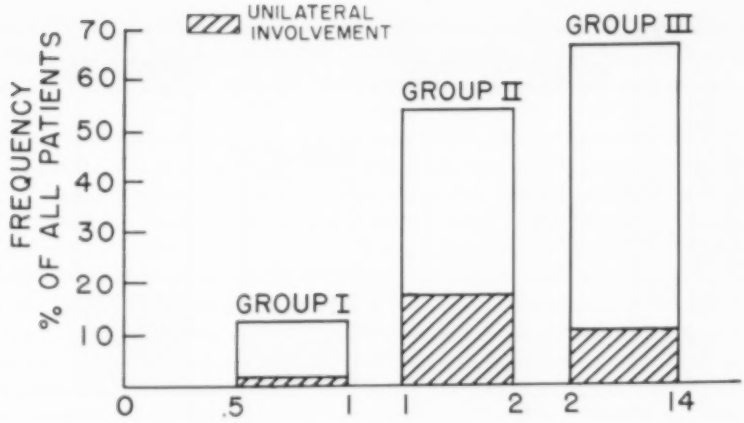
1. It might appear that the tempo of the entire disease process is accelerated with increasing amounts of retained radioactive elements within certain limits;

2. When malignant changes occur, the clinical course is no longer dependent on the amount of retained radium. The average time from the onset of symptoms at the site of tumor origin until death in the 1931 series with larger amounts of retained radium was about the same as that in the 1951 series. It has been about 1.5 years in all patients in whom malignant tumors have developed.

Roentgenographic Changes

The most important contribution to the more accurate establishment of maximum permissible body burdens for radium has been the ability to correlate the frequency of skeletal roentgenographic findings with the amount of radium in the body within a certain range. Much more reliance can now be placed on the permissible body burden of radium as a result of the increased roentgenographic changes found in patients having over one microgram of radium when compared with those having under one microgram.

Thirty of the patients who were given radium for medical reasons and two luminous-dial workers were selected because each of these patients had had a complete skeletal roentgenographic examination. They were arranged in order of increasing amounts of retained radium from 0.5 to 14 micrograms, and the skeletal changes characteristic of the deposition of radioactive elements were tabulated. These patients were arbitrarily divided into three groups, those patients having between 0.5 and one microgram of retained



RETAINED RADIUM μg

	15 PATIENTS	8 PATIENTS	9 PATIENTS
SKULL	1	4	6
RADIUS	1	6	6
ULNA	0	4	5
TIBIA	1	3	6
FIBULA	3	5	7

CHART I

Frequency of skeletal roentgenographic changes (areas of decreased density) in the three groups of patients.

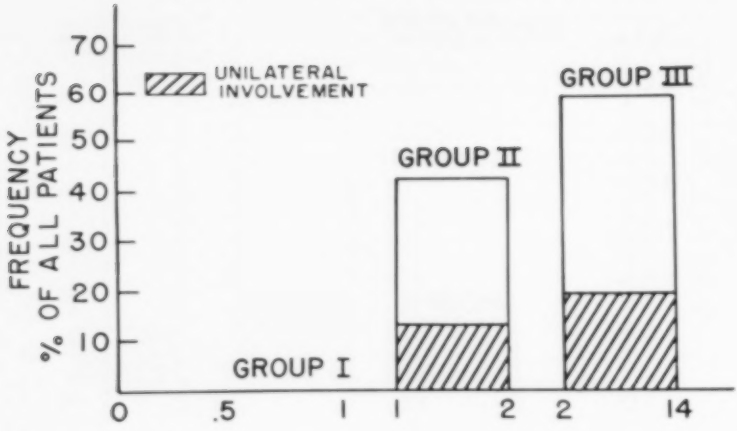
radium, those having between 1.1 and two micrograms, and those having between 2.1 and fourteen micrograms. Table I gives the age and sex of thirty-two patients twenty-one years after the deposition of radioactive materials.

Forty individuals were selected at random while undergoing physical examination at the Argonne National Laboratory for skeletal roentgenographic examination to act as a control group. It would have been desirable to have matched controls; however, the results of these roentgenographic examinations greatly minimized the possibility of the minor changes being present to any significant degree in the general population.

The five bones which were most frequently the sites of decreased density were first tabulated (Chart I). The frequency of involvement was expressed as a percentage of the total number of bones that could possibly be involved. No distinction was made between unilateral or bilateral involvement, since the long bones were involved bilaterally in all but about 10 to 20 per cent of the cases.

For example, in the fifteen patients having between 0.5 and one microgram of radium, a total number of seventy-five bones could be involved; only six bones had changes characteristic of radium deposition or about 10 per cent of the total number of bones. In Group II, about 55 per cent of the bones had characteristic changes, and in Group III about 65 per cent of the bones were involved. Charts II and III demonstrate that a similar relationship exists between the retained radium and bones most commonly the sites of increased density and bones most commonly the site of aseptic necrosis.

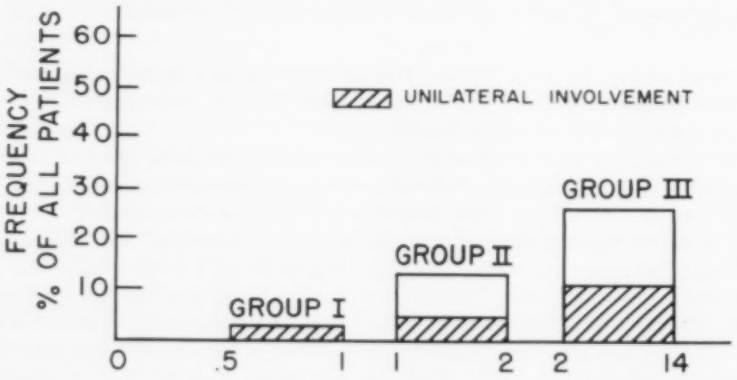
Attempts were made to find some correlation between the severity of bone changes and increasing amounts of radium. The skeletal changes were divided into six grades of



RETAINED RADIUM μg	15 PATIENTS	8 PATIENTS	9 PATIENTS
FEMORAL HEAD	0	5	5
GLENOID PROCESS	0	3	6
HUMERAL HEAD	0	2	5

CHART II

Frequency of skeletal roentgenographic changes (areas of increased density) in the three groups of patients.



RETAINED RADIUM μg	15 PATIENTS	8 PATIENTS	9 PATIENTS
MANDIBLE	0	1	2
FEMORAL HEAD	1	2	3
BONES OF FEET	0	1	2

CHART III

Frequency of aseptic necrosis in the three groups of patients.

severity [15]. With increasing amounts of retained radium in the body a proportional increase in roentgenographic changes does not occur. In addition, there is a marked individual variation in the amount of retained radium in the body. In some patients who had the greatest amounts of retained radium, only minor changes occurred, while other patients who had only one-fifteenth to one-thirtieth as much had more severe skeletal changes. Chart II graphically demonstrates this clinical observation in regard to the roentgenographic changes. Patients in Group III had about five times as much radium as those in Group II; however, there is only a 10 per cent increase in the frequency of involvement. This lack of correlation between Group II and Group III is further emphasized by the fact that the average age of Group III is sixty compared with an average age of fifty in Group II. This finding and the finding of a significant increase in roentgenographic changes and symptoms (see Part II, Tables IV and V) at one microgram, even though the luminous-dial workers were thirteen years younger, are suggestive that age at the time of deposition is not a major factor in the eventual production of roentgenographic changes. The fact that some of the patients had between 0.1 and 0.5 microgram of radium deposited for twenty-five to thirty years and had no roentgenographic changes is suggestive that time of retention *per se* may not be a major factor in the eventual production of roentgenographic changes. It is to be emphasized that these observations, suggesting that the time of deposition and the length of retention are not important, may well be the result of biased sampling of the patients, as well as an inadequate number of patients.

The most important result of these studies is that a definite correlation has been made between an objective clinical finding and the estimated amount of radioactive element retained in the body. For the first time, a semiquantitative relationship between the frequency of the roentgenographic changes and retained radium has been established within a certain dose range. No characteristic roentgenographic changes have been observed in patients having under 0.1 microgram of radium and relatively few changes have been found in patients having between 0.1 to 0.5 microgram of radium. Between 0.5 and one microgram of radium changes began to occur with increasing frequency and those patients having over one microgram of radium had a considerable increase in the frequency of the roentgenographic changes when compared with the patients having under one microgram of radium.

Clinical Changes in the Luminous-Dial Workers and Radium Patients in Relation to the Estimated Amount of Radium in the Body

The recent Chicago and Boston investigations were initiated because of the necessity to evaluate more critically the maximum permissible levels of body burden. Preliminary results from one of these investigations led to the belief that mesothorium I was one of the primary causes for the clinical changes in these patients. This larger and more unselected series indicates that the clinical differences found in the patients who had received radium medically and the luminous-dial workers are greatly minimized.

Mesothorium I * is an isotope of radium and it would be expected to have similar biological characteristics. At the time the changes usually began to occur in these patients (fifteen to thirty years), only about 10 per cent of the mesothorium I would be present even if none of the mesothorium I was eliminated. If we assume that all but 0.1 to 10 per cent of the mesothorium I was eliminated initially, then only from 0.1 to 0.01 per cent of the original mesothorium would be present at the time significant clinical changes began to occur.

The time relation in this question is very important. If it is assumed that reversible changes are produced by the presence of mesothorium, then its major clinical effect should have been expended before the changes began to occur in these patients. The available clinical data supports the assumption even though the possibility of delayed effects can-

* Physical half-life, 6.7 years.

not be dismissed. Roentgenographic changes do not begin to occur until fifteen to thirty years after the deposition of the radioactive elements. However, once changes begin to develop in these patients there is usually a gradual increase in the frequency and the severity rather than a decrease. Further work is in progress in an attempt to clarify the relationship between the effects of mesothorium, radiothorium, and radium and the clinical changes observed.

Results of the Boston and Chicago Investigations in Relation to Maximum Permissible Body Burden

The maximum permissible levels for the radioactive materials in medical, military, and industrial use today are based in large measure on radiobiological data obtained from the luminous-dial workers and from patients given radium. The clinical material available was small at the time the permissible body burden of 0.1 microgram was established for radium. These two large series of cases recently evaluated have given enough clinical data so that reliance can be placed on the results of the correlation of clinical changes with the amount of radium in the body. The new and more refined techniques have made possible the more accurate determination of the radioactive elements in the body. The radiobiological data obtained by the newer techniques have given a better understanding of the manner in which changes are produced by radioactive elements.

Even though these investigations have permitted the more accurate establishment of the permissible body burdens for radium, the concept of correlating clinical data with the amount of a radioactive element in the body does not seem adequate. The results of these investigations indicate that the relation between the destructive effects of the radioactive elements remaining in the body for long periods of time and the clinical changes produced is a dynamic relationship between the destructive and reparative processes of the body. For example, some of the patients had aseptic necrosis of the femoral head with less than one microgram of radium while others with ten micrograms or more had no deleterious effects. It is reasonable to assume that these patients had other disturbances in the femoral head, such as an unsatisfactory blood supply. The body is able to compensate for the unsatisfactory blood supply, but it is incapable of compensating for the combined effects of the radioactive element and the unsatisfactory blood supply. Another example of the dynamic relationship was demonstrated in the patient who had increased changes during pregnancy which subsided with the delivery of the child. Still another possibility is that certain periods of increased bone destruction or reduced bone formation may occur from disease processes which later revert to normal. One patient had rather severe changes in the mandible which later subsided.

Based on this additional information, a more flexible concept for permissible body burdens seems to be in order. This may be illustrated in the following manner. Conditions *A* and *B* acting in conjunction with the destructive effects of the radioactive element in question may cause clinical changes at one microgram; the radioactive element and the destructive bone condition *A* may cause damage at five micrograms, while the radioactive element alone may cause damage at ten micrograms. Further extension of this concept may be necessary. Reduction of the time of development of irreversible changes may have to be taken into consideration. If there is an unsatisfactory blood supply of the femoral head which causes necrosis at the age of sixty without the presence of radium, it is reasonable to assume that it might occur at the age of forty as a result of the effects of both radium and poor blood supply.

The marked increase in the use of radioactive materials may necessitate the determination of the increased risk of clinical changes with increasing amounts of radioactive elements in the body. Further study may demonstrate that an individual may have only a 5 per cent increase in the possibility of aseptic necrosis of the femoral head developing with five micrograms of retained radium as compared with that in a person with one

microgram. The risk of aseptic necrosis of the femoral head developing at the age of forty in a person with five micrograms may be 1 per cent greater than that at age fifty in a person with one microgram of retained radium. The same criteria for permissible body burdens for an employee of fifty years of age need not necessarily apply to an employee of twenty years of age. The employee of fifty would in all probability run a far greater risk of dying from some of the diseases of old age than from having difficulty from the effects of radioactive element deposition some twenty-five years later.

Caution should be exercised in attempts to raise the permissible body burden for radium. The average age of the patients studied was about fifty years. It is possible that increased changes may occur with increasing age. Results, however, from the evaluation of the older patients indicate that this possibility is unlikely.

SUMMARY

Fifty patients who were given radium salts either orally or intravenously for medical purposes and twenty-eight luminous-dial workers who ingested or inhaled radium, mesothorium, or radiothorium, or all three, were recently evaluated.

If enough radium is in the body to produce clinical changes it can be detected by radiochemical analysis of the faeces, collection of radon in the breath, or by external counting. The history of radium intake and the characteristic skeletal roentgenographic changes are usually sufficient in order to establish the diagnosis of the deposition of radioactive elements. A negative history of radium intake does not rule out this possibility since some of the patients did not remember receiving radium. Any patient with a malignant tumor, skeletal roentgenographic changes characteristic of the deposition of radioactive elements, or unexplained aseptic necrosis should be evaluated in regard to previous exposure to or administration of radioactive materials.

The amounts of radium remaining in the skeletons of these patients were estimated by measuring the amount of radon, the first daughter element of radium, given off in the breath, and by measuring the gamma-ray activity given off by the body.

Almost all of the radium is rapidly eliminated so that at one year only about 0.1 to 10 per cent of the initial amount is still present. Smaller and smaller fractions of the radium body content are excreted with increasing time after administration. The coefficient of elimination after twenty years is about .02 to .016 per cent of the body content.

Radium is deposited in small highly concentrated areas irregularly distributed throughout the skeleton. The concentration of radium in samples from various parts of the skeleton in one patient varied by a factor of ten *. It is reasonable to assume that radium concentration in some of the Haversian systems will have many times the upper limits of these variations because of the inherent difficulties in bone sampling.

Atypical osseous tissue in trabecular spaces is a characteristic histopathological finding following the deposition of radioactive elements. Small areas of increased density were found in cancellous bone on skeletal roentgenographic examination as a result of the atypical osseous tissue. Small well differentiated areas of destruction were found in compact bone. Small areas of decreased density were found in compact bone on skeletal roentgenographic examination as a result of the destroyed bone. These changes developed years after the deposition of radioactive elements. The humeral and femoral heads, glenoid processes, and bones of the feet most frequently had areas of increased density. The long bones and skull most frequently had areas of decreased density.

In the autoradiographic, roentgenographic, and histopathological studies on bone specimens, radium was found as often in the absence of histological change as in the presence of histological change. Because of this lack of correlation of the deposition of radio-

* Patient M. K. (R-24) had a total body radium content of 1.3 micrograms and weighed approximately sixty kilograms. The average skeletal dose would be about 0.1 roentgen equivalent physical per day (assuming 6000 grams of skeleton and 60 to 70 per cent exhalation of radon). The radiation dose in some of the Haversian systems could be in the range of one to five roentgen equivalent physical per day.

active elements and pathological change it is considered that the deposited radioactive elements initiate a sequence of events that eventually produce pathological alterations. These changes are probably the result of many augmenting factors such as trauma, damage to blood supply, decreased bone repair, and increased bone destruction. It is evident that the relationship between the deposition of radioactive elements and skeletal change is complex. Therefore, it is reasonable to conclude that when the destructive effects of the radioactive elements and one or more of the augmenting factors become greater than the reparative processes, permanent alterations in the skeleton occur.

The destructive effects of the deposited radioactive elements made the skeleton more fragile so that aseptic necrosis and fractures of the bones subjected to the greatest stress frequently occurred. Symptoms were similar to those following skeletal destruction from other causes.

The anaemia that developed was usually not pronounced. Poikilocytosis, anisocytosis, and hypochromia seem to occur more frequently in patients having over one microgram of retained radium compared with those having under one microgram. The erythrocyte-sedimentation rate was almost always above 20 millimeters in one hour.

Management of these cases consists primarily in vigilance in regard to the development of malignant tumors and orthopaedic care for skeletal lesions. Roentgenographic examination of any site at which pain persists is the most practical method for the early detection of malignant change. This should be followed by biopsy of any areas which are suspicious on roentgenographic examination and by surgical removal if the presence of malignant change is confirmed. A repeated roentgenographic examination every one to three years is important for following the course of the disease, for the early detection of malignant change, and for the accumulation of valuable information on the late effects of internally deposited radioactive elements.

In the well advanced stages of the disease, supportive measures and relief of pain are of primary concern. The severe anaemia that develops infrequently is usually refractory to therapy, so that transfusions are the only satisfactory means of management. ACTH and cortisone have given some relief from pain.

The patients were divided into two groups and the time from the deposition of the radioactive elements until symptoms developed was compared. The average time for symptoms to occur in the two groups was about fifteen years, even though the second group of patients had from ten to 100 times as much retained radium in their bodies as the first group. The mean age at the time of deposition for the luminous-dial workers was twenty-one years contrasted with thirty-four years for the patients who had been given radium. Almost no clinical changes and no tumors developed in either the luminous-dial workers or patients who had been given radium who had under 0.5 microgram of retained radium in their bodies. In addition there were almost no roentgenographic changes found in the few patients who had under 0.5 microgram of radium and in whom deposition occurred as much as thirty years before.

Attempts at correlation of the roentgenographic changes, symptoms, and tumor formation with increasing amounts of radium were made. A proportionate increase in the severity of the clinical changes with increasing amounts of radium in the body was not found. However, there was a marked variation in the clinical response when related to the amount of radium present in the body. Some patients who had ten to fourteen micrograms of radium in their bodies had minor changes while others having as little as 0.5 to 1 microgram of radium had major skeletal changes or tumor formation. This great variation in clinical response emphasizes the importance of the dynamic relationship between the destructive and reparative processes of the body in the eventual production of clinical change.

A definite correlation exists between the frequency of skeletal roentgenographic change and tumor formation and the retained radium within a certain range. A marked

increase in frequency of roentgenographic changes was found in patients having over one microgram of radium compared with those patients having under one microgram. The patients, who were evaluated, were about fifty years of age and had had radium present in their bodies for about twenty-five years. The frequency of malignant neoplasms of the skeleton was 14 per cent. All malignant tumors occurred in patients who had 0.5 microgram or more radium in their bodies.

CONCLUSIONS

The relationship between the deposition of radioactive elements in the body and the production of tumors, anaemia, and skeletal changes was established more than a quarter of a century ago. Information from studies on patients who had received radium medically and employees of luminous-dial-painting factories were the foundation upon which our levels of maximum permissible body burdens were built.

These two large series of patients recently evaluated have given enough clinical data so that much greater reliance can be placed in the results of the correlation of clinical changes with the amount of radium in the body. The new and more refined techniques have made possible the more accurate quantitative determination of retained radioactive elements.

It has been possible to establish a semiquantitative relationship between the frequency of the roentgenographic changes and the amount of radium in the body within a certain dose range.

Results of studies of these two large series of patients indicate that the relationship between the destructive effects of the radioactive elements remaining in the body for long periods of time and the clinical changes produced is a dynamic relationship between the destructive and reparative processes of the body. Based on this additional information it is considered that a more flexible approach to permissible body burdens is in order. It is reasonable to conclude that one or more destructive processes may act in conjunction with the deposited radioactive element to produce changes in the presence of much smaller amounts of retained radium than if the radioactive element were the sole etiological agent. Proper evaluation of the different conditions which may be present with the deposited radioactive element as well as the probability of their occurrence is necessary for more flexible interpretation of maximum permissible body burdens. It is possible that permissible body burdens may be significantly elevated without increasing to a great degree the risk of difficulties from the deposition of radioactive elements if proper evaluation of the possibility of other conditions which may act concomitantly with the radioactive element is made.

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DISCUSSION

Dr. Justin J. Stein, Los Angeles, California: Dr. Looney is to be congratulated for this excellent work. He has emphasized the fact that the use of radioactive materials is rapidly increasing in medicine, industry, in the armed forces, and in research, and that so little is known about the late effects and the tolerance dose in man.

It has been an uphill fight to convince many individuals of the tremendous necessity for studying the late effects of internally deposited radioactive materials.

The experiences recorded from investigations of the cases of radium poisoning in the luminous-dial workers, of those who drank radium water for the treatment of arthritis, or who received injections of radium for the treatment of Hodgkins disease, arthritis, and other conditions, served as the nucleus for information regarding the late effects of radioactive materials taken internally.

Efforts can be made to guard against or to minimize the effects of external radiation but internal radiation must be prevented if at all possible.

Many radioactive elements are produced in the fission of uranium. Strontium, barium, tellurium, iodine, and cesium are fission products which are absorbed from the digestive tract to an appreciable degree. There is a tendency or avidity of the long-life fission products and actinide elements (elements above actinide on the periodic table) for absorption in bone. The late effects of plutonium must also be studied.

The long half-life of some of the bone-seeking elements presents great hazards. By biological half-life is meant the time required for one-half of the material to be excreted. The effective half-life is the time required to lose one-half of the material by the combination of excretion and radioactive decay. The physical half-life of radium is 1620 years, of strontium ^{90} twenty years, and of plutonium ^{239} 24,300 years. It is readily appreciated therefore that only a minute amount of any of these elements fixed in the skeletal system can be very harmful and that it may take a long period of time before the clinical findings are evident.

The possibility of the use of thermonuclear weapons in the next war is very great and the public health problem of preventing the internal ingestion or inhalation of the fission products will be difficult. The inhalation of fission products from the "fall out", from dust, and from their ingestion by eating contaminated food, or the consumption of meat from animals who have lived on food stuffs which have been contaminated, and many other sources of contamination requires that we, as physicians, learn as much as possible about both the early and late effects of radioactive materials in man.

Although it cannot be predicted which individual will be adversely affected by radioactive isotopes taken internally, the fixation of minute amounts in bone may severely disable the individual. Death does not usually result directly from the effects of the isotope unless a malignant lesion has been produced.

Aub and his associates (1952) have shown the great variability in the amount of internally deposited radium required to produce symptoms and also the spotty distribution of radium in bone. Some of their cases lived for many years in reasonably good health despite fixed amounts of ten micrograms, eleven micrograms, and twenty-three micrograms of radium in their bodies. It was their opinion that radiation damage to bone caused the death of patients only when malignant change occurred in radiation-injured tissues.

(Continued on page 420)

NOTE: The basis of this Symposium is the survey made under the direction of the Committee for the Study of Femoral-Head Replacement Prostheses, the results of which were published in the October 1954 issue of the Academy Bulletin. From that survey, 68 per cent of those replying to the questionnaire requested or were in favor of a Symposium in which various phases of this problem could be openly discussed.

It was felt that having some of the figures in the survey high-lighted and explanations given to some portions of the report that might not be clear would be the role of the Moderator.

Two discussors were selected who, the Committee felt, had had wide experience in this field and yet had no personal interest in any particular type of prosthesis, so that a more objective viewpoint might be possible.

Two discussors were selected who had had considerable experience with the use of replacement prostheses and yet were not carried away with this operative procedure and who could give a critical analysis of some of the problems involved and stress some of the deficiencies of such procedures.

Symposium on Femoral-Head Replacement Prostheses *

BASED ON THE REPORT OF THE COMMITTEE FOR THE STUDY OF FEMORAL-HEAD REPLACEMENT PROSTHESES AS PRINTED IN THE OCTOBER (1954) ISSUE OF THE BULLETIN

THE COMMITTEE: LEE RAMSAY STRAUB, M.D., DONALD E. KING, M.D., AND CLAUDE N. LAMBERT, M.D., *Chairman*

CLAUDE N. LAMBERT, M.D., CHICAGO, ILLINOIS, *Moderator*

Claude N. Lambert, M.D.: The second survey of clinical experience with hip prostheses was conducted by the Committee for the Study of Femoral-Head Replacement Prostheses of The American Academy of Orthopaedic Surgeons consisting of Claude N. Lambert, M.D., *Chairman*, Lee Ramsay Straub, M.D., and Donald E. King, M.D. It covered the period from October 1952 to October 1954. There were more replies to the questionnaire than in the previous survey, and the data are based on more material, 8,384 prostheses as compared with 6,156.

Approximately 766 men or roughly 42 per cent of the Academy Membership replied. Of these, 570 were using some form of prosthesis and 196 were not.

The total number of prostheses inserted during this two-year period was 8,384. The average duration of follow-up was 18 months.

Inquiry as to the age of patients operated upon revealed a range of from 2 to 101 years, with an average of 62 years.

TYPES OF PROSTHESES

Thirty-one different types were reported to be in use. The number of times each type was mentioned in the replies was determined. The results were: Eicher, 159; Judet (all types), 147; F. R. Thompson, 120; Moore, 104; Naden-Reith, 48; and J. E. M. Thomson and Roger Anderson, 14 each. The remaining types were mentioned anywhere from 1 to 11 times.

Similar data were obtained with regard to the types of prostheses which had been used for a while and then abandoned. Results were as follows: Judet (all types), 177; Eicher, 30; Naden-Reich, 23; Collison, 22; and J. E. M. Thomson, 11. In addition there were 12 other types occasionally mentioned as being abandoned, including the Roger Anderson, 9; the Minneapolis, 7; the F. R. Thompson, 5; and the Moore, 2.

There were 19 members who had used some form of prosthesis a total of 82 times and then stopped using prostheses entirely.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, January 30, 1955.

INDICATIONS

Data accumulated concerning the indications for the use of hip prostheses are recorded in terms of the number of men who reported using a prosthesis for the lesion in question. Approximately 16 different indications were reported. The more important of these were non-union (reported by 295), arthritis (by 266), aseptic necrosis (by 236), fresh fractures (by 235), old congenital dysplasia or dislocation of the hip (by 18), pain (by 13), old slipped epiphysis (by 10), old Legg-Perthes disease (by 10), and tumors, primary or metastatic (by 9). Other indications were mentioned occasionally, including Charcot joint (reported by 4), acute hip dislocation (by 3), and radiation necrosis (by 3).

COMPLICATIONS

Accurate information concerning complications was not obtainable. Some replies merely mentioned a certain complication while others gave actual numbers of cases. It would appear that the figures obtained for each complication are low.

Protrusion of the stem from the shaft was reported as having occurred one or more times by 68 men: 51 men did not specify the type of prosthesis; 5 reported protrusion with the Thompson; 5 with the Eicher; 3 with the Moore; 2 with the Naden-Reith; and 2 with the Judet types.

Intrapelvic protrusion was reported by 4 men and migration of the acetabulum was reported by 4 men. One surgeon reported that in one patient a Charcot joint developed.

Instability of the prosthesis due to bone absorption was reported by 85 men in all: 66 reported instability with the Judet, 6 with the Naden-Reith, 3 with the Eicher, 3 with the F. R. Thompson, 3 with the J. E. M. Thomson, 1 with the Roger Anderson, and 3 with an unspecified type of prosthesis.

Dislocation of the prosthesis from the acetabulum was reported as occurring one or more times by 246 men: 204 of those reporting dislocation of the prosthesis did not specify the type of prosthesis. Sixteen men reported dislocation with the Judet, 12 with the Eicher, 5 with the F. R. Thompson, 4 with the Naden-Reith, 2 with the Moore, 2 with the Minneapolis, and 1 with the J. E. M. Thomson.

Fracture of the femur was reported by 124 surgeons, 27 of whom did not specify the type of prosthesis. Of the remainder, 26 reported fracture of the femur with the Eicher, 6 with the Moore, 6 with the F. R. Thompson, 3 with the Minneapolis, 1 with the Collison, and 1 with the Judet.

Many *deficiencies of the prostheses* were reported. Breaking of the device was most common, 120 surgeons reporting this complication. Of these, 46 reported deficiencies of the Judet, 20 of the Collison, 18 of the Eicher, 5 of the Lorenzo, 2 of the McBride, and 2 of the Roger Anderson; 1 reported breakage of the Moore, 1 of the Naden-Reith, 1 of the Stuttle, 1 of the Eaby, and 1 of the Fixel.

A *nylon reaction* or pitting of the nylon was reported by 49 surgeons and *wearing* of the acrylic head was reported by 5.

Mechanical failure, type unspecified, was reported by 5 men.

Postoperative pain in the hip was reported by 223 men. One reply, covering a large series, indicated that 20 to 30 per cent of the patients had pain.

Stiffness of the hip was reported by 53 surgeons.

The incidence of *postoperative infection* could not be determined accurately but 113 men reported infections—one reported a fatal infection, another reported infection requiring hip disarticulation.

Calcification about the hip was reported by 24 surgeons and ankylosis by 4.

Weakness or limp was reported by only 30 men, but two of those reporting stated that all patients limped.

Sciatic paralysis was reported by 4 men; *peroneal paralysis* was reported by 1.

Too tight a fit with *squeaking* in the joint was reported by 2 surgeons.

Other complications common to all surgery included *thrombophlebitis* (reported by 20), *pulmonary embolism* (reported by 8), and *psychosis* (reported by 1).

Only 14 surgeons reported that they had had no complications.

SUMMARY

As an indication of trends in the use of these devices, it was found that 137 men were using prostheses increasingly, 233 less frequently, and 121 had made no change in the use of prostheses or made no comment.

In the previous report, the Judet types were the most frequently used, while this survey shows a marked increase in the use of metallic prostheses with an intramedullary stem such as the Eicher, the F. R. Thompson, and the Moore. Almost invariably when a member stated that he had changed the type of prosthesis used, he had abandoned the Judet in favor of one of the metallic intramedullary types. In the present report the Eicher, the F. R. Thompson, the Moore, and the various types of the Judet prostheses were used by 95 per cent of those reporting.

The indications for the use of prostheses appear to be becoming more clearly defined. Non-union, arthritis, and aseptic necrosis are almost universally accepted as indications, while the use of prostheses in fresh fractures of the femoral neck at any age, but in the aged particularly, is increasing.

Complications were numerous and varied. With the intramedullary prosthesis, as with the Judet types, protrusion of the tip of the stem through the lateral side of the femoral shaft with a resultant painful area was reported frequently.

Stiffness of the hip was common. No relation of this to the type of prosthesis could be determined from the data available.

Dislocation of the prosthesis from the acetabulum was common. Although the type of prosthesis was usually not specified, this complication did not appear to be related to the type of prosthesis employed. Dislocation seemed to be less common when a postero-lateral (Gibson) incision was used. It is noted that most men using an anterior incision now employ a plaster boot with a crossbar in order to control rotation and to prevent dislocation.

Fracture or splitting of the femur has been a rather common complication. In most instances the type of prosthesis was not specified. However, the large stem of the Eicher type seemed to produce a greater number of fractures than did the stems of the other types.

Breaking of the prosthesis was reported to occur most commonly with the Judet type. The Collison prosthesis had been used by 22 men, 20 of whom reported a broken prosthesis. Eighteen surgeons reported failure of the Eicher prosthesis.

Pain in the hip postoperatively was a common complication.

Loosening of the prosthesis in the femur was reported more frequently from the use of the Judet prosthesis than with any of the other types. A rocking motion of the stem of the prosthesis within the neck and trochanter resulted in the patient having a feeling of instability.

A significant number of men reported reactions to nylon. Reactions were characterized by pain, swelling, and limitation of motion. At the time of surgical removal, marked pitting and evidences of degeneration of the prostheses were found. The use of the nylon prosthesis is definitely contra-indicated.

From the general tenor of the reports, it is concluded that although more surgeons are using prostheses, there is not the wild enthusiasm noted in the previous survey. Indications are becoming more strict and better established; the technique has improved; and three main types of prostheses have emerged as the ones in common use: (1) the original Judet acrylic prosthesis with the Judets' latest modification, (2) the metallic version

of the Judet prosthesis, and (3) the metallic intramedullary types. Use of these latter types is increasing rapidly.

Carl E. Badgley, M.D., Ann Arbor, Michigan: It was with reluctance that I agreed to take part in this Symposium. The dissenter is always at a disadvantage, certain to arouse hard feelings.

In order to clarify our attitude upon this subject, it should be stated at the outset that we believe there is a place for the prosthesis when salvage is the primary aim. Its use signifies a confession of the failure of other methods of treatment.

We will illustrate the successful use of a cup arthroplasty in a case of osteo-arthritis of the hip, and a very successful use of the Frederick Thompson hip prosthesis in a fracture-dislocation of the hip. [Lantern slides were shown to illustrate the pathological condition and motion pictures were used to demonstrate the excellent functional results five years after operation in the case of the cup arthroplasty and three years in the case of the Frederick Thompson prosthesis.]

Experience in the past thirty-five or more years in bone and joint surgery has convinced me of the inability of any foreign material to take the place of bone for any length of time. The ever-present ability of bone to alter and adjust itself physiologically to various stresses by complicated methods of repair and adaptation is lacking in any foreign material.

The tendency of all metals and of all plastics under stress and strain to alter their molecular arrangement eventually, to crystallize, and even to break is well known to the chemists and manufacturers.

The assay of the strength of material must include assay of its durability.

The natural reaction of our tissues to the presence of a foreign substance incorporated within them is to attempt to exclude that substance from the body. A tissue reaction is set up at the contact zone. This reaction may be benign, consisting in tissue resembling synovial membrane seen along the pathway of a well secured Vitallium nail or in the orderly healing about a Vitallium cup; on the other hand, this tissue may grow very actively and proliferate resentfully, as in a violent foreign-body reaction, such as one sees in reactions to polythene and to nylon prostheses.

A postoperative infection following the insertion of a prosthesis is a tragedy. The reaction to the prosthesis in this situation exemplifies how impractical it is to attempt to replace the femoral head. Every effort is made by nature to get rid of this foreign body. I think we all will agree that in the presence of infection, the prosthesis should be removed as quickly as possible. I am fully aware of the famous case of Bohlman and Moore in which such a tragedy did occur. Here the extracortical prosthesis could not be removed. However, new bone grew into it. This unusual case cannot be a guide. It is possible that the syphilitic reaction may have been a factor.

In the event of non-union following fixation of a fracture with a metal plate, the characteristic findings are (1) fracture of the plate or screws, (2) a typical soft-tissue reaction, and (3) the frequent development of a spontaneous infection. This result does not speak well for metal substitution. The findings from the use of the Collison-Jaenichen prosthesis were akin to this.

The cup arthroplasty stimulated the development of the prosthesis. Its influence is well illustrated by the prosthesis in which a Smith-Petersen cup is fixed by a Smith-Petersen nail to the neck of the femur. The Judet prosthesis similarly resembles an assembled cup and nail, although it is made of plastic material. However, there is a basic difference between a Vitallium cup and a replacement prosthesis. The principle feature of the Vitallium cup is that it is an inert intervening material which ideally lies free between the components of the joint, molding the joint surfaces so as to adapt them to the transmission of stresses. The cup is used as a constructive guide to the healing process within the body.

Originally Smith-Petersen intended to remove the cup once the joint had developed. We have removed the cup in a number of cases and hip joints with fair function, and stability with minimal pain has resulted.

In the fascinating history of the development of arthroplasty of the hip, the cup supplanted interposing vital tissue such as fascia lata and introduced the mold concept which was entirely new.

The *basic principle of the prosthesis* is quite different. It is most important to recognize that metal replacement introduces a new and, to me, a frightening period of experimental surgery. One must call it a "mechanistic period"; certainly it is not biological.

The principle of the prosthesis is not to attempt to produce a joint by the healing powers of the body, but, rather to replace the defective joint by an inert mechanical device to which the bones and soft tissues must adapt themselves. This new approach to the formation of a functional joint is without question unproved and experimental. I regret the reckless abandon with which prostheses have been utilized clinically in the recent past. Experimental surgery should not be accepted as a daily procedure in clinical practice until sufficient evidence of its soundness has been evidenced.

The more one considers the serious errors which have resulted from the violation of the body with prostheses made of materials such as polythene and nylon, the more one is convinced of the need, following Barr's recommendation, for an act to control the materials placed within the body akin to the Pure Food and Drugs Act.

Now we are confronted with sincere and earnest scientists in allied fields who have joined orthopaedic surgeons in an all-out effort to develop prostheses. As the result of scientific studies made in association with chemists and engineers, a false head and a false acetabulum have been introduced as a universal joint with true matching spherical articular surfaces to eliminate wear and strain. The use of fast-setting dental acrylic has been introduced as a means of cementing the component structures securely in place.

Recently experiments were reported on the possible use of self-curing methyl methacrylate in orthopaedic surgery. Prostheses have been welded to the femur with this dental acrylic and have remained intact for as long a period as three years.

The substitution prosthesis is without question still in the experimental phase.

Nonetheless at the present time, it has very definite clinical value. Prostheses have proved to be the most comfortable and the most prompt method of mobilizing the elderly patient. Furthermore, we believe that prostheses have a definite value in salvaging the hopeless fracture of the femoral neck or the fracture which has healed poorly in the elderly patient. Fixation of a fracture of the neck of the femur when possible is, however, so much more certain of enduring success that only for salvage should a prosthesis be used.

In cases of multiple injuries including fractures, it may be necessary to utilize the prosthesis in order to maintain function elsewhere.

Some tumors may be excised and replacement prostheses used.

I would not quarrel with the judicious use of the intramedullary prosthesis in the elderly individual in whom there has been a loss of substance from the head and neck of the femur. The problem of aseptic necrosis and non-union in the elderly patient might well be attacked best by the use of an intramedullary prosthesis.

In a younger individual, I would certainly prefer the use of a cup arthroplasty or a reconstructive procedure which promises to endure under conditions of normal activity.

The modern prosthesis is well enough developed and the surgical technique sufficiently improved to eliminate the vast number of complications previously recorded.

The lateral or posterior approach with freeing of the capsule from the femur instead of from the acetabulum has prevented dislocations. A point of great help to us has been the partial division of the glutaeus maximus tendon and the tensor fasciae latae to allow downward traction so that the head can easily be placed into the acetabulum. One to one and one-half inches can be gained in this way.

We advocate the use of the prosthesis only as a salvage procedure. We compliment and encourage the research workers in this field. They may well find ways and means to perfect what is as yet frankly experimental surgery except in case of necessity.

I wish to close by quoting Dr. Gallie—"Look to the great principles of anatomy and physiology to maintain our position rather than the simple mechanics of the machine shop."

Mark B. Coventry, M.D., Rochester, Minnesota: All of us on this panel recognize that anything said today regarding the femoral-head prosthesis must be in the form of a preliminary report, based on only some 5 years' experience with it. Nevertheless, certain impressions and ideas—if not facts—have come out of this experience. I should like to report on the patients operated upon at the Mayo Clinic for replacement of the femoral head during the years 1951, 1952, and 1953. This gives a minimum follow-up period of 1 year. By a careful evaluation of the results in these patients it may be possible to formulate the indications for femoral-head arthroplasty.

BACKGROUND

A very few (3) acrylic stem prostheses were first used. However, because of a fear that acrylic would be more subject to wear and to fatigue fracture than Vitallium, we decided to use the Vitallium stem prosthesis. This prosthesis was of the Judet type, but the stem was triflanged. However, with the use of this prosthesis, loosening of the stem in its channel, the development of "wobble", cutting of the prosthesis through the neck with resultant varus position, and absorption of the neck beneath the head of the prosthesis were found to occur. Accordingly we gradually abandoned the stem-type of prosthesis and began to use the intramedullary type developed by A. T. Moore. We have used this type since about the middle of the year 1952. Altogether, in the three years mentioned, we have performed 185 operations (14 bilateral) on 171 patients. In 78 of these patients a Vitallium stem prosthesis of the Judet type was used, while in the other 93 a Vitallium intramedullary prosthesis of the Moore type was employed.

COMPLICATIONS

The complications are shown in Table I. No prostheses have broken. There has been only 1 "delayed" or late dislocation or subluxation, which occurred with a stem prosthesis. This type of prosthesis became loose in a fairly large number of patients, resulting in pain. Of these patients, 8 have undergone reoperation; and several more should be operated on again. One intramedullary prosthesis has been removed because of infection—the only reoperation in the patients with the intramedullary prosthesis and the only infection in the entire series. We observed no gross loosening or migration of the intramedullary prosthesis during this time.

RESULTS

While it is too early to discuss results with any certainty, our impression at the present time is that in arthroplasty of the hip, in comparable patients, the intramedullary prosthesis will give a result which is as good as, or better than, that obtained with a Vitallium mold or cup.

INDICATIONS

With this analysis as a background, the indications for femoral-head arthroplasty become clearer (Table II). In addition to the patients with primary conditions which we think can best be helped by replacement of the femoral head, there is the large number of patients who have had unsuccessful operations on the hip previously. This is, at times, an indication in itself (Table III).

TABLE I

COMPLICATIONS OF FEMORAL-HEAD PROSTHESIS (1951–1953)

	Cases	
Stem prosthesis		
Loosening (varus, "wobble", absorption of neck)		*
Reoperation		8
Reinsertion of stem prosthesis	2	
Removal and insertion of Moore type	5	
Cutting off end of stem	1	
Dislocation		3
Immediately after operation	1	
Five days after operation	1	
Late (50 per cent subluxation)	1	
Excessive periarticular-bone formation with resulting ankylosis		1
Intrapelvic protrusion		1
Moore prosthesis		
Removal because of infection		1
Fractures of shaft		2
At time of operation	1	
Two weeks after operation	1	

* More than 50 per cent of patients—exact number not known.

CONCLUSIONS

What, then, in the light of our present knowledge, are our conclusions regarding the surgical replacement of the femoral head?

1. Since our results with the Vitallium, Judet-type of stem prosthesis have been unsatisfactory, we have discontinued using it.

2. The intramedullary prosthesis (our experience has been solely with the A. T. Moore type) has proved a valuable adjunct to restoration of hip function in the following situations:

a. Bilateral affections of the hip, in which arthrodesis would be contra-indicated.

b. Unilateral affections of the hip in which there is lack of viable bone in the head or neck of the femur. Avascular necrosis of the femoral head secondary to fracture or dislocation and non-union of fractures of the femoral neck are our most common

TABLE II

INDICATIONS FOR FEMORAL-HEAD PROSTHESIS (1951–1953)

	Cases
Fracture	
Old, with non-union or avascular necrosis or both	73
Fresh	10
Osteo-arthritis (idiopathic, or secondary to acetabular dysplasia, slipped capital femoral epiphysis, trauma, chondrodystrophy, and old gun-shot wounds)	66
Rheumatoid arthritis or spondylitis	11
Arthrokatadysis	5
Idiopathic avascular necrosis	2
Irradiation necrosis	2
Tumor	
Bone cyst	1
Osteochondroma	1
Total	171

indications at present. We utilize, of course, other procedures, such as arthrodesis, Colonna reconstruction, and McMurray osteotomy for patients with such affections.

c. Osteo-arthritis and rheumatoid arthritis are usually treated equally well either with mold arthroplasty or with a prosthesis unless there is evidence on roentgenographic examination or at the time of operation that the head of the femur is avascular or extensively cystic. In such cases we elect to use a prosthesis. We have observed many mold arthroplasties with necrosis of the bone within the mold and pain. In this regard it is to be noted that 20 prostheses were used in patients who had undergone previous unsuccessful mold arthroplasties.

TABLE III

OPERATIONS PRIOR TO USE OF FEMORAL-HEAD PROSTHESIS (1951–1953)

	Operations	
Internal fixation for fractured femoral neck		60
Arthroplasty		21
Vitallium mold	19	
Lucite mold	1	
Fascia lata	1	
Prosthesis		11
Minneapolis	1	
Eicher	1	
Nylon	1	
Collison	1	
Stem (Judet type)	7	
Bone graft to femoral neck		6
McMurray osteotomy		6
Brackett reconstruction		3
Attempted arthrodesis		1
Total		108

d. Only fresh fractures of the femoral neck in the very aged or in those with a poor prognosis (fracture line approaching the vertical or inadequate reduction and fixation) should be treated by a femoral-head prosthesis until more is known about the ultimate fate of this device.

3. There are contra-indications to the use of the femoral-head prosthesis. Chief of these is youth. Only in rare instances, when no other procedure can be expected to give as good a functional result, do we use the femoral-head prosthesis in the younger age group.

Previous infection in the hip is another contra-indication, and in most such cases arthrodesis or the Colonna type of reconstruction is the procedure of choice.

The use of a femoral-head prosthesis in patients with marked bone atrophy is hazardous. Although this is not an absolute contra-indication to the intramedullary type of prosthesis, extra care at the time of operation and during convalescence is needed.

An inadequate acetabulum is a contra-indication to this procedure, unless the acetabulum can be reconstructed at the time of operation so as to be congruent with the prosthesis and give the new joint stability.

In summary, in our hands the intramedullary femoral-head prosthesis of Moore has been a valuable adjunct to restoring function of the hip in selected patients. Time alone will tell whether bone atrophy will eventually develop about the prosthesis, whether prostheses will fatigue and fracture, or whether acetabular changes will occur which nullify an otherwise good result. Until then, a most conservative attitude should be maintained toward surgical replacement of the femoral head.

Carroll B. Larson, M.D., Iowa City, Iowa: A prosthetic replacement demands very little on the part of the body in the way of repair in contrast with a mold arthroplasty in which both joint surfaces must be reconstituted. With the use of a prosthesis one-half of the joint is replaced by a non-yielding metal. The function of the joint must, therefore, be altered in some way and to considerable degree.

Localized pressure on bone tends to cause necrosis. Non-union of a fracture fixed by a plate and screw offers a familiar example of this. The screws become loose due to necrosis and absorption of bone. Any non-yielding material which moves and causes pressure may lead to necrosis of tissue at the area of contact.

These known facts raise certain questions, the answers to which we do not know.

Will pathological changes occur as the result of the abnormal joint function after prosthetic replacement? If so, how long will it take for them to become manifest?

Instances have been reported of absorption of bone about the stem of all types of prostheses and of intrapelvic protrusion of the head of the prosthesis.

Since only the passage of time and careful observation will answer these questions, it seems obvious that for the present at least, we should be conservative in the use of these devices perhaps limiting their use to cases requiring salvage.

Philip D. Wilson, M.D., New York, N.Y.: The forthcoming remarks relative to the use of the short-stem or Judet-like hip prosthesis should be prefaced by the reminder that this method represents a modification of hip arthroplasty. It involves a *new and as yet unproved principle*—that of substituting a metallic or plastic counterpart for a portion of the skeleton and fixing it in place. There is no reason to expect that through its use all the problems of hip arthroplasty will be solved. Prosthetic replacement, no matter what kind, has been used very much, too often without attention to the principles and requirements for success in hip arthroplasty. Its apparent suitability to the so-called "unsolved fracture" where only one side of the joint has to be reconstructed, has led many surgeons to use the method inadvisedly. Hence, the increasing disrepute of this resection-reconstruction operation—an undeserved fate for a relatively untested new technique which is proving in our hands to be a significant contribution to arthroplasty of the hip.

MATERIAL FOR STUDY

The present report is based on the study of a series of a little less than 150 cases. The patients were operated upon by Members of the Attending and Resident Staffs at the Hospital for Special Surgery since September 1950. In the large majority of the first 50 patients an acrylic prosthesis was used, the stem of which was reinforced with metal. Since then, the Vitallium head with a three-flanged stem has been used predominantly. Sixty-three cases have been followed for more than 1 year and 33 of these for 2 years or more. The longest follow-up is a little more than 4 years.

PATHOLOGICAL FINDINGS

Opportunity to examine the prosthesis *in situ* has arisen in 6 patients. In only 1 of these, 3 years after operation, did the acrylic head show signs of wear, being slightly flattened on its superior surface apparently due to the fact that it was too small for the acetabulum and had subluxated slightly laterally. Although a few other instances of *slight* erosion of an acrylic prosthesis have been reported to the author, the resistance of this material to wear is considerably greater than that of nylon which has proved to be an entirely unsuitable material for prosthetic construction. In none of our patients was there any sign of an inflammatory response. Tissue tolerance of the acrylic resin and of Vitallium alloy seemed excellent. Four of the patients * showed loosening of the prosthesis. In all of

* One of these patients is not included in the statistics, since the original operation had been performed elsewhere.

these the prosthesis was acrylic and the channel about the stem in each was found to be lined by fibrocartilaginous and hyalinized tissue containing minute bony particles. Tissue of similar type had formed under the edge of the rim of the prosthesis. In every instance, the prosthesis was difficult to remove because of suction between it and the surrounding tissue.

CHANGES OBSERVED IN FOLLOW-UP ROENTGENOGRAMS

Adaptive changes in the bone surrounding the stem of the prosthesis can be studied in postoperative roentgenograms. As far as the channel for the stem and the acetabulum are concerned, these changes are easier to interpret with the Vitallium prosthesis than with the acrylic prosthesis, for the outline of the former is distinctly visible roentgenographically. The fate of the bone collar under the rim of the prosthesis, however, can better be followed with the acrylic prosthesis than with the Vitallium prosthesis. Since the main purpose of prosthetic emplacement is to obtain a firm fixation of the artificial head, these changes are of the greatest interest in so far as they indicate loosening. Loosening is demonstrated on the acetabular side of the joint by subluxation or dislocation, and on the femoral side by absorption of bone or shift of the prosthesis or both.

Instability of the Prosthesis in the Acetabulum

Actual dislocation of the reconstructed hip as a postoperative complication has occurred in 3 patients, all of them early in the series, and each time as the result of a sudden twist. Each dislocation was reduced by manipulation and a relatively stable hip resulted after adequate immobilization. Of greater interest, however, are the cases of subluxation (6 patients), especially those which progressed gradually (2 patients). Several technical faults of emplacement have led to this complication and all of them are recognizable in postoperative roentgenograms. They are as follows:

1. *Failure to reconstruct an adequate acetabulum:* A well shaped acetabulum in which the prosthetic head fits accurately is essential for stability. Patients with fractures of the femoral neck, except for the selection of the right-sized head, present no problem; the acetabulum has only to be cleaned of scar tissue and of bony débris. Acetabular reconstruction is most difficult in patients with arthritis, particularly those with osteo-arthritis secondary to congenital hip dysplasia. Even with special reamers and gouges this part of the reconstruction is often difficult. Obviously a wide exposure is necessary; a straight anterior, muscle-separating incision is not sufficient. In malum coxae senilis an adequate acetabulum can usually be obtained, but in congenital dysplasia of the hip there is often so much distortion of the pelvis that it is impossible to construct an entirely satisfactory acetabulum.

2. *Prosthetic head too small for the acetabulum:* If the head fits the acetabulum accurately, atmospheric pressure prevents it from migrating outward, even when the exposed hip is manipulated at operation. If the head is too small for the acetabulum, however, this additional source of stability does not exist. Although dislocation did not occur in several instances when the head was too small, the weight thrust was concentrated on a small part of the roof and the load was not effectively distributed. The only instance of wear of an acrylic prosthesis in this series occurred when the head was too small.

3. *Too much anteversion of the prosthesis:* If an adequate acetabulum has been constructed and a head of suitable size has been inserted, minor degrees of anteversion have not impaired the stability of the hip. However, one will usually note at the completion of the reconstruction that if there is anteversion of the prosthesis, the most unstable position is one of external rotation. The greater the degree of anteversion, the more this instability is manifest, especially if the anterior rim of the acetabulum is not well developed. This difficulty is most likely to arise in cases of congenital hip dysplasia, particularly when the acetabulum is very oblique and the femoral head is badly flattened.

4. *Short femoral neck:* Shortness of the femoral neck results in a relaxed joint. Such a hip will dislocate or subluxate more readily than one with normal neck length. When the neck is short, the prosthesis should be placed in some valgus in order to ensure better fixation. This will, of course, aggravate the tendency for the hip to dislocate as the thigh is adducted. Instability in such a case can, however, be controlled very adequately by accurate fitting of the head to the acetabulum, together with distal transfer of the greater trochanter with its attached gluteal muscles. When this was done, we had no difficulty with dislocation or subluxation despite the fact that postoperatively we used only balanced suspension or a plaster boot fitted with a platform to hold the extremity in internal rotation.

5. *Resection of the capsule:* In our experience, resection of the capsule with or without the reflected head of the rectus femoris has not significantly affected the stability of the hip as long as the other four conditions have been provided for.

Loosening of the Prosthesis in the Femoral Neck

The first indication of loss of fixation of a prosthesis in the femoral neck is widening of the stem channel outlined by a thin zone of bone condensation around the stem. Although widening of this channel has been seen in 24 of the 60 cases which have adequate follow-up, the widening has progressed in only 8 cases (13 per cent) to a point where there are other changes to indicate actual loosening. In the other 16 cases, the increased width of the channel is not particularly alarming and cannot be interpreted as a sign of significant loosening, since it has not increased. This narrow radiolucent space seen about the stem has become manifest as early as 6 months after the operation and has then remained static for as long as 3 years (that is, at the time of this study).

Absorption of the neck, an hour-glass configuration of the stem channel, and actual shift of the prosthesis are of course indications of true loosening. These changes have been found in 5 cases and they appear to be developing in 3 more, bringing the total to 8 (13 per cent). In retrospect, it seems that the complication could have been avoided in all instances by better emplacement. Six of these patients came to operation because of femoral-neck fractures. It is in this group, by-and-large, that it has proved most difficult to obtain a satisfactory emplacement of the short-stem prosthesis.

Study of the postoperative roentgenograms suggests that several factors predispose to loosening of the prosthesis:

1. *Bone atrophy:* In the presence of osteoporosis, the medullary cavity of the neck of the femur is enlarged; this makes it difficult to obtain good fixation of the prosthetic stem. Under these circumstances, it may also be difficult to gain secure fixation of the long stem or intramedullary prosthesis. Under such conditions, the short-stem prosthesis should be placed in much more valgus than is usual, in order to achieve the best fixation. The tip of the stem should still, however, pierce the lateral cortex.

2. *Shortness of the femoral neck and unnecessary sacrifice of neck length:* Loosening of the prosthesis could be attributed in most instances in this series to too short a femoral neck. In cervical fractures with non-union or with comminution of the inferior cortex of the neck, the surgeon must do the best he can with an unfavorable situation. However, in the arthritic hip, care should be taken not to sacrifice too much of the neck. In the latter instance, the transverse osteotomy should be made well up in the cartilaginous portion of the head and the osteophytes should be trimmed away from the circumference of the neck. When there is aseptic necrosis, the bone is often of poor quality and shattering may occur, particularly when the original Judet acrylic prosthesis is used. Reaming of the cortex requisite to the insertion of this type has often led to crumbling of the bone and necessitated a lower emplacement than was originally intended. With the Vitallium short-stem prosthesis, however, the cortex can be preserved and no such complication has occurred.

3. *Varus emplacement of the prosthesis:* Emplacement of the prosthesis in varus

was observed in 19 cases, but surprisingly enough actual loosening occurred in only 3 patients. In 2, the femoral neck was very short and this seemed to be the more significant factor in causing the loosening. In the third, a case of rheumatoid arthritis, there was a moderate degree of osteoporosis. The conclusion can be safely drawn that, in the presence of bone atrophy, a short neck, or other factors weakening fixation, the prosthesis should be inserted in a valgus position in order to minimize the possibility of loosening. This is especially so in cases of fracture of the femoral neck. Here, one must get as vertical an emplacement of the prosthesis as one can and the angle of valgus should be greater, the greater the shortening of the neck. There are 3 cases in the series in which a short-stem prosthesis had been placed directly on the upper end of the shaft of the femur with the stem in the medullary canal. Results have been very satisfactory, although, as seen by roentgenograms, all show widening of the stem channel. From this, it should not be inferred that a short-stem prosthesis is considered preferable to the intramedullary type in these cases. These instances are cited merely to emphasize the importance of a valgus emplacement. Actually, with the short-stem prosthesis, the stem should always pierce the lateral cortex in order to obtain the best fixation possible.

4. *Failure of the prosthetic stem to pierce the lateral cortex:* This occurred in 9 cases in this series. In only one was there any indication of loosening of the prosthesis and this was not apparent until 3 years after operation. Fortunately in this case the prosthesis was placed in some valgus and even now, 4 years after operation, the loosening has not as yet detracted significantly from the clinical result. In this connection it should be noted that the Vitallium short-stem prosthesis has a rather dull point and unless the lateral cortex is pierced prior to its insertion, the stem may be deflected and remain within the medullary canal. In this series there have been no complications as a consequence of the prosthetic stem projecting too far through the lateral cortex. For this reason it would seem safer to select a prosthesis with a stem a little too long rather than too short.

IDEAL EMPLACEMENT

From the foregoing discussion, it is now possible to understand what constitutes an ideal short-stem prosthetic emplacement. The importance of achieving as good an emplacement as possible must be stressed. Not one patient with proper relation of the prosthesis to the femur and to the acetabulum has shown signs of loosening. The principles of the technique of insertion that are important to emphasize are:

1. *Preserve neck length*: Save as much neck length as possible. Osteotomize through the femoral head, not below it. In patients with arthritis, marginal spurs always tend to be misleading to the surgeon; the tendency is to remove more bone than is necessary.

2. *Proper size of prosthesis:* Select a prosthesis that will fit the acetabulum snugly and also one which will fit snugly on the neck without sacrificing cortex.

3. *Center the prosthesis well:* Center the prosthesis in the neck accurately and keep the angle of anteversion as near the normal as possible.

4. *Make the acetabulum concentric:* In the arthritic patient, construct an acetabulum which will fit the head snugly.

5. *Trim osteophytes:* Trim the osteophytes from neck and margin of the acetabulum.

6. *Have the stem long enough:* Make sure that the stem is long enough to pierce the lateral cortex.

7. *Insertion of the prosthesis in valgus position:* Judge the angle of emplacement according to neck length available, but always err on the side of valgus; the shorter the neck, the greater should be the degree of valgus.

8. *Shift of trochanter:* Shift the greater trochanter distally if the neck is short so that muscle leverage will be re-established.

9. *The blood supply of the neck:* Do not strip the neck of soft-tissue attachments any more than is necessary so that the blood supply will not be impaired.

RESULTS

Our early results from the use of the short-stem prosthesis have been considerably better than they were from Vitallium-cup arthroplasty. The postoperative morbidity has been reduced and the patients have recovered more motion, or as good motion, with less effort. Fewer secondary procedures have been necessary. The assumption seems fairly safe that these facts will remain the same, since only 1 of 31 cases followed for two years or more has shown signs of deterioration after seeming to do well at first. Our experience in the past four and one-half years has encouraged us in the use of the short-stem prosthesis instead of cup arthroplasty.

We have not treated enough patients with severe hip dysplasia or rheumatoid arthritis or with previous infection to indicate whether this newer procedure will be any more satisfactory in overcoming these difficult problems than was the older one. The results in osteo-arthritis, however, have been quite encouraging with 21 satisfactory results out of 24 cases with adequate follow-up. This has also been true in the cases with healed fractures of the femoral neck complicated by aseptic necrosis of the femoral head. Here, there have been 9 satisfactory results from 11 operations. In ununited femoral-neck fractures, on the other hand, the results have been less good with 8 satisfactory results from 12 operations. It is in this group that we have learned that the technique of emplacement must be modified in order to accommodate for the loss of the length of the femoral neck. We have treated very few patients with recent fractures by means of this technique; all of these were eighty years of age or more. Although the follow-up is inadequate, it is our impression that the results will be comparable with those in patients with non-union.

The main question in analysis of the results in these cases, however, is whether the wedding of the inert prosthesis to bone can survive over a long period of time. Although there is as yet no final answer, the indications so far are that it can survive, at least for the space of a few years, and that errors in technique of emplacement which lead to loosening will usually make themselves manifest in the first or second postoperative year.

INDICATIONS FOR THE USE OF THE SHORT-STEM PROSTHESIS

We have come to use the short-stem prosthesis wherever a Vitallium cup would formerly have been used. There is little if any more sacrifice of bone involved and our early experience has been more satisfying. Thus, the indications in this trial series of cases have been the same as those for arthroplasty in general. Our unfavorable results have led us not to abandon the procedure but rather to modify it.

The method seems best suited to patients who have osteo-arthritis and fracture of the femoral neck complicated by aseptic necrosis. For rheumatoid arthritis and degenerative joint changes consequent to congenital dislocation of the hip, no definite statement can be made at this time, although the few cases in our series show satisfactory early results.

In ununited fractures of the femoral neck, the procedure can be recommended, but with the important reservation that the surgeon must be prepared to do a radical reconstruction of the upper end of the femur. It is impossible to estimate accurately from preoperative roentgenograms the integrity and length of the femoral neck, but if the general principles requisite to achieving good short-stem prosthetic emplacement are followed, the surgeon can modify his operative procedure according to the findings at the time of surgery. It is in this group that the long-stem or intertrochanteric type of prosthesis may find greater usefulness than the short-stem prosthesis.

Duncan C. McKeever, M.D., Houston, Texas (by letter): The statistics recorded and the cases cited in this Symposium really shed no light on the basic question of whether replacement of the femoral head by a prosthesis is feasible or not. There are three fundamental factors which must be considered in this connection (1) the technique of insertion, (2) the design of the prosthesis, and (3) the reaction of the tissues.

Obviously the surgical technique must be correct for any procedure to be consistently successful.

Similarly, the prosthesis must be of proper design to function under the mechanical conditions imposed in each case. The mere fact that a given prosthesis works part of the time, most of the time, or even all of the time is no guarantee that it is in fact correctly designed.

Finally, the metabolism of the tissues is certainly a determining factor in the success of this procedure. The patient's nutritional state should first be determined. If this is found to be subnormal it must be restored before a prosthesis may properly be used. Otherwise, absorption of bone may take place at stress points and actual intrapelvic protrusion may occur.

Normal nutrition must be maintained following the introduction of the prosthesis as long as the patient lives.

The tissues, of course, must react to the presence of the prosthesis by a foreign-body reaction, the degree of which will depend on the chemical and physical properties of the material from which the device is made. Regardless of this, a layer of connective tissue forms in contact with the prosthesis and is shaped and modified by the mechanical barrier presented by the geometrical arrangement of the device. Similarly the trabecular structure of the bone in relation to the prosthesis, particularly at the points where stress is transferred from the prosthesis to the bone, is revised to conform to the lines of stress. These known reactions, and doubtless others, which are as yet unknown, will determine the eventual result.

It should be emphasized, therefore, that in the study of this problem the only results which are significant are the failures and successes which occur with a properly designed prosthesis which has been inserted with correct surgical technique on a patient whose tissues react in a favorable fashion.

DISCUSSION

Late Effects of Radioactive Materials

(*Continued from page 406*)

As a result of investigations such as made by Dr. Looney much needed additional knowledge can be gained as to how much local and total body radiation can be tolerated by the human being and also as to which tissues are the most susceptible to radiation. The knowledge of the inherent dangers of internally deposited radioactive materials and a high index of suspicion on the part of the physician especially when studying roentgenograms of the skeletal system will be most helpful in the early diagnosis.

Upper-Extremity Prostheses in Juvenile Amputees *

BY CLAUDE N. LAMBERT, M.D., CHICAGO, ILLINOIS

From the Department of Orthopaedic Surgery of the University of Illinois College of Medicine, Chicago

INTRODUCTION

About three years ago, it was this author's privilege to attend the pilot training class for upper-extremity prostheses, held at the University of California at Los Angeles, which was sponsored by the Committee on Artificial Limbs of the National Research Council and the Veterans Administration. In addition to observing the manufacturing of the prostheses and the training of the amputees, the chief lesson learned was that the approach to the amputee's problem is ideal if it is made by a team of specialists competent to deal with every aspect of it, and that such a team approach is very highly recommended for any amputation program.

TABLE I

SIXTY JUVENILE PATIENTS WITH UPPER EXTREMITY AMPUTATIONS*

Level of Amputation	No. of Congenital Amputations		No. of Surgical Amputations		Total
	Male	Female	Male	Female	
Above the elbow	6	3	4	3	16
Below the elbow	17	19	9	1	46
Elbow disarticulation	0	0	1	0	1
Shoulder disarticulation	2	2	0	0	4
					67*

* Discrepancy in these figures is due to the fact that there were seven patients who had more than one amputation.

An amputee clinic was subsequently established at the University of Illinois in the Department of Orthopaedic Surgery. The number of amputees was, and continues to be, far larger than was ever anticipated. Although this report is concerned only with a portion of the total group of amputees seen in the Clinic during the past three years, it might be of interest to remark on the number of amputee patients seen during this period. There were 248 patients (174 males, 74 females) ranging in age from four months to seventy-seven years. The adult patients numbered 143, and there were 105 juvenile patients, of whom sixty had upper-extremity amputations and fifty-seven had lower-extremity amputations (the discrepancy in the total is due to the fact that some patients had both upper-extremity and lower-extremity amputations).

JUVENILE PATIENTS WITH UPPER-EXTREMITY AMPUTATIONS

This report is concerned only with the sixty juvenile patients who had congenital and surgical upper-extremity amputations. It is felt that the problems arising in the prescribing, making, and fitting of *lower-extremity* prosthetic devices for juveniles are likely to be the same as for adults, but that the problem of making *upper-extremity* prostheses for juveniles has been far more difficult than for adults, has received far less attention until recently, and the benefit to this group from the developments in this

* Read at the Annual Meeting of The American Orthopaedic Association at White Sulphur Springs, West Virginia, June 19, 1955.

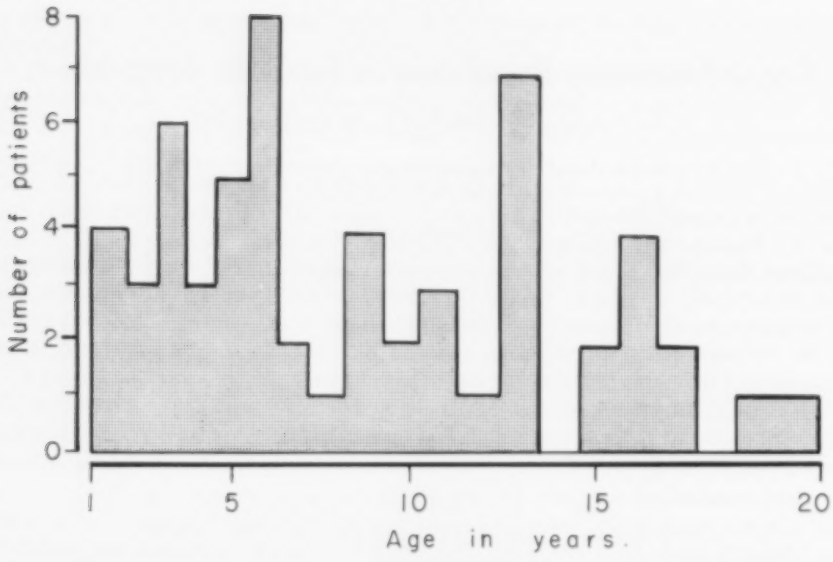

CHART I

field are very great. The classification of these sixty juvenile amputees is shown in Table I, and the distribution according to the age when the child was first seen in the Clinic is shown in Chart I.

When this program was first begun, the age of twenty years was established as the dividing line between juvenile and adult patients. Up to twenty years of age, most amputee patients are either of pre-school age or are attending school, and it is felt that these children have slightly different problems than those who have finished school. An arbitrary age of five years was taken as the youngest age at which prescription and fitting of a prosthesis was considered practical. Having had no experience with such functional prostheses as the more recently developed "California" type, we selected this age of five with respect to the capabilities of the child to undertake the amount of training that is necessary. Also, it seemed that it would be advantageous to the child to have a prosthesis and to learn to use it during the year before he started the first grade in school. He would thus be adjusted to it by the time he entered school. It was very soon apparent that an even younger child will adapt to the prosthesis much more readily than the five-year-old, and a younger child actually needs even less training. As a result, the age for a prosthesis has been lowered and lowered; up to the present time the youngest child to have been fitted with an upper-extremity prosthesis in this series was twenty-two months of age. It would seem that this is about the minimal age, but more time and more experience may lower this age.

The manufacturing of small prostheses has not been too difficult, and the prosthetists have taken a keen interest in making even the tiny ones, but there is a limit to this smallness. Early in the program, the elbow-joints were made too large, and the smaller youngsters found them too difficult to manipulate, but the manufacturers of these parts have made smaller ones which are easier to manipulate. With three exceptions, all of the prostheses prescribed in this series have been equipped with a voluntary-opening hook as the terminal device. It may be asked why the hands designed by the Army Prosthetics Research Laboratory (APRL) have not been used. The answer is simple. First of all, a small-size hand has not been made. Secondly, the cost of the APRL hand is almost prohibitive for a charity clinic. The three patients for whom APRL hands have been pre-

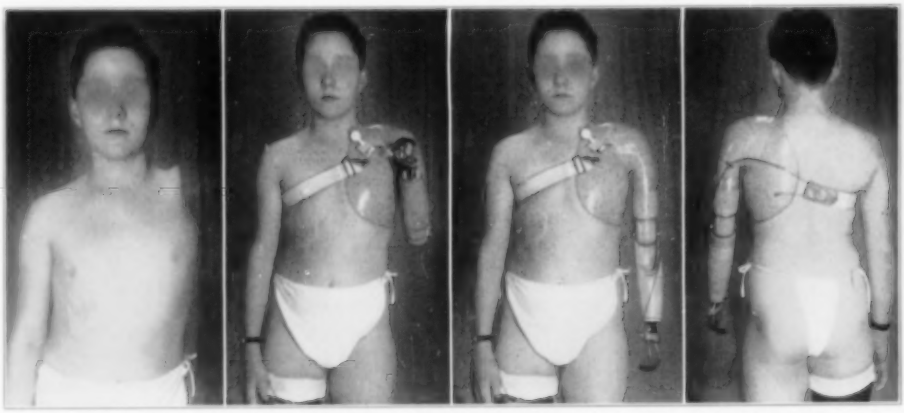

FIG. 1-A FIG. 1-B FIG. 1-C FIG. 1-D

Congenital shoulder disarticulation with shoulder-disarticulation type of prosthesis. Fig. 1-B shows how the patient could flex the prosthesis, raising the hook to the shoulder.

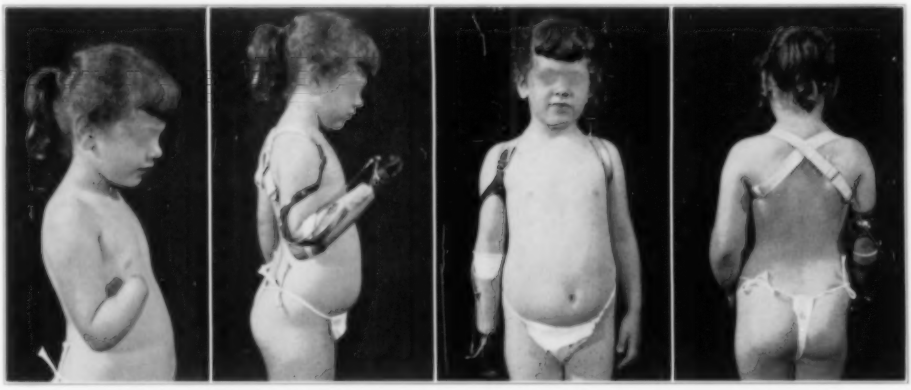

FIG. 2-A FIG. 2-B FIG. 2-C FIG. 2-D

Congenital below-the-elbow amputation with below-the-elbow prosthesis, flexible hinges, and hook. Fig. 2-B shows patient flexing prosthesis to raise hook.

FIG. 3-A FIG. 3-B FIG. 3-C FIG. 3-D

This patient who had congenital disarticulation of the right shoulder, above-the-elbow amputation on the left, and bilateral absence of the femora, was fitted with an above-the-elbow prosthesis. Fig. 3-C shows voluntary flexion of the prosthesis.

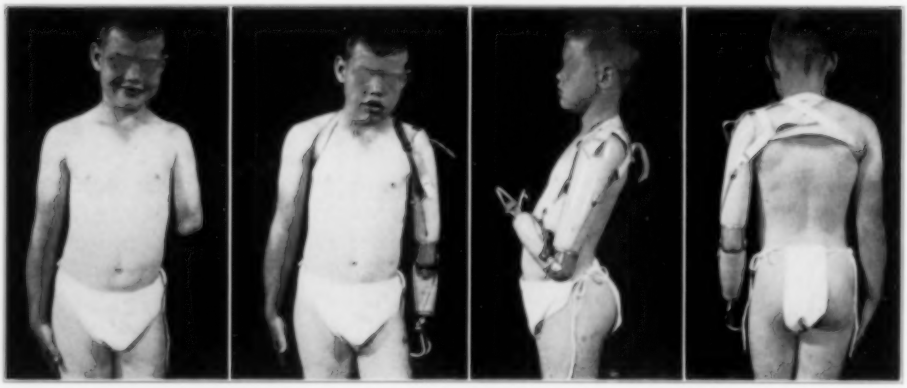

FIG. 4-A FIG. 4-B FIG. 4-C FIG. 4-D

A patient with an above-the-elbow amputation following an injury was equipped with an above-the-elbow prosthesis which had an elbow joint and hook.

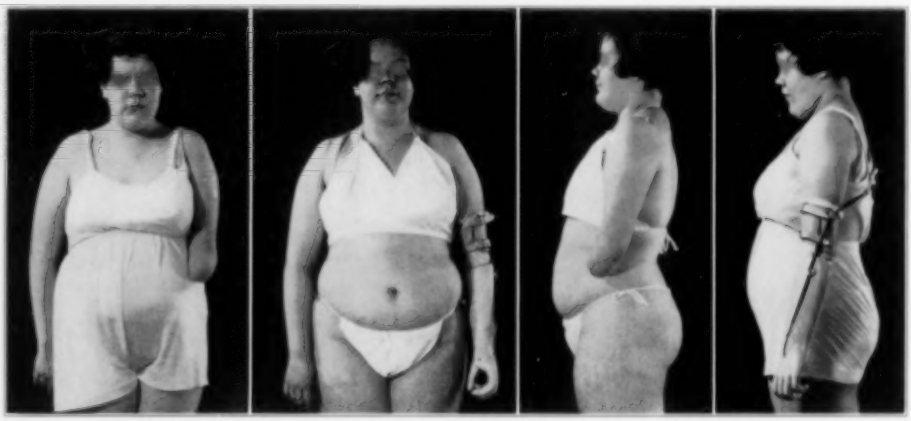

FIG. 5-A FIG. 5-B FIG. 5-C FIG. 5-D

Short below-the-elbow type of prosthesis with step-up hinges and hand designed by the Army Prosthetics Research Laboratory.

scribed were in the older group, ages seventeen to twenty, and even then, it was only because very definite psychological reasons outweighed the functional advantages of a hook.

In only one instance did the parents object to the child having a hook as the terminal device. The patient was a pretty five-year-old girl. The father insisted upon a hand. When it was explained to him that such a small hand was not as yet available, he stated that he would rather see his daughter dead before allowing her to have and use a hook, and they left the Clinic. The daughter is the one who will suffer. This is mentioned only to show that a great deal of education of the parents must be given in many instances.

This need for education is not limited to the parents. Some schools will not allow a child with a hook as the terminal device to attend school, primarily because of the possibility that in a fight or in games damage could be inflicted on others by such a hook. This is a theoretical consideration, and in none of the patients in this series has such a history of injury to others been reported. One of the first patients, a boy of eleven with a surgical above-the-elbow amputation, was fitted with a prosthesis that had a hook as the terminal device. Upon his return to school, he was elected captain of the basketball team and played

TABLE II

JUVENILE PATIENTS FITTED WITH UPPER-EXTREMITY PROSTHESES

Type of Prosthesis	No. of Congenital Amputees		No. of Surgical Amputees		Total
	Male	Female	Male	Female	
Above-the-elbow	6	2	3	1	12
Below-the-elbow	13	9	2	2	26
Shoulder-disarticulation	2	1			3
Cosmetic hand	1	1			2

basketball without injury to others. Further education must be given to the amputee's playmates, as well as to society in general. The child who is fitted with a prosthesis early in life grows up with it and, seemingly, so do his playmates. They regard the prosthesis as a part of the individual and pay little attention to it. However, in the older age group, the appearance of the newly acquired prosthesis causes much curiosity, at times to the point of embarrassment.

Of all of the young patients in this series for whom prostheses with a hook as the

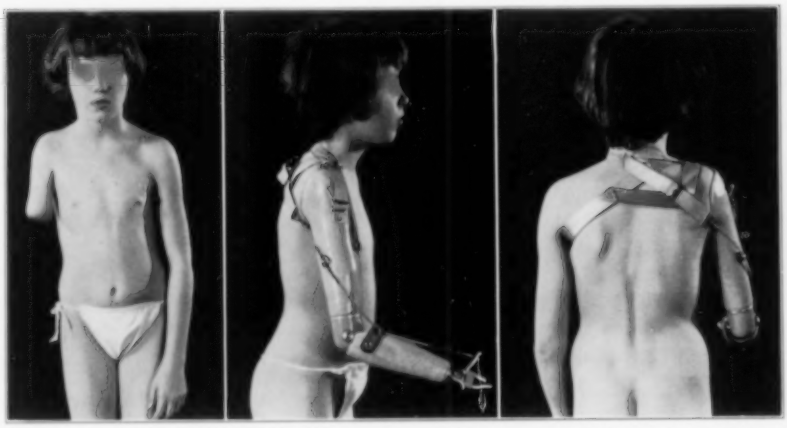

FIG. 6-A FIG. 6-B FIG. 6-C

Patient fitted with typical above-the-elbow prosthesis.

terminal device have been prescribed, there has been only one, so far, who has suddenly objected to using the hook. A girl of twelve had worn her prosthesis for two years and had really used the hook. At her last visit, she requested a hand,—the reason, adolescence and an interest in the opposite sex. After it was explained that the present hands were too large, that smaller ones would be available in the not-too-distant future, and that she could then have one, she was satisfied and promised to continue using the hook. However, this problem will come up again and again, as the smaller youngsters grow up, and it is sincerely hoped that smaller hands will be available for selected cases. It is not advocated that all juvenile amputees be supplied with APRL hands, as the hook will still be the most useful terminal device for most amputees.

The questions of breakage and of how long these prostheses will last before being out-grown or worn out have arisen. There have been only two broken prostheses in the series. One of these, an above-the-elbow prosthesis worn by a ten-year-old boy, was broken while he was branding and roping calves. He had wrapped the rope around the

prosthesis and had then snubbed the rope with the prosthesis. It was considered that this had certainly placed exceptional strain on the prosthesis. As to growth and wearing-out, it is probable that at least some part of the prosthesis will have to be replaced every two years; if the control cables wear out, it is a good indication of the use of the prosthesis.

Most of the congenital type of amputations require either no surgery or minimal surgery. Occasionally, a small underdeveloped digit or a "bud" may be removed for better fitting of the prosthesis, but in no instance has reamputation at a higher level been necessary. It is practically a rule, in congenital amputations, not to perform a surgical reamputation, but to leave everything; for example, if wrist bones are present, they are left untouched, and the child is considered to have a long, below-the-elbow type of congenital amputation. If the ulna is so short that the child cannot be fitted with the usual below-the-elbow prosthesis, an above-the-elbow type of prosthesis is modified to include the ulnar stump. With further growth of the child, the short ulna may grow sufficiently so that later in life a below-the-elbow type of prosthesis may be used. In none of the congenital amputees has the bone of the stump grown out through the skin. In the patients with surgical amputations, it has sometimes been necessary to reamputate in order to eliminate projecting bone or adherent scars.

Some surgeons maintain that, if repeated reamputation is necessary, the wearing of a prosthesis should be delayed until full growth has been attained. We do not consider this to be sound thinking. The functional advantage to the child from a prosthesis during the growing period more than offsets any necessity which may arise for reamputation. However, in the patients with surgical amputations, as well as in those with congenital amputations, all bone length should be preserved as much as possible.

SUMMARY

Sixty patients under the age of twenty with sixty-seven amputations of the upper extremities have been seen in the Clinic in the past three years. Prostheses have been prescribed and fitted for forty-three, and these patients have received adequate training in the use of the prosthesis. For nine other patients, prostheses have been prescribed and ordered, but they have not yet been received from the manufacturer. Some patients are still too young, being under twenty-two months of age, for a prosthesis. This series does not include patients with partial amputation of the fingers, or those children who have only two digits which could be surgically treated by opposing one to act as a thumb.

DISCUSSION

Dr. Rufus H. Alldredge, New Orleans, Louisiana: When I saw Dr. Lambert's patients in Chicago last fall I was highly impressed. The work he has done in organizing a clinic and applying the modern principles of rehabilitation to juveniles with the newer prostheses for the upper extremity is an example of what can be done by anyone who is interested, and it will serve as an inspiration to those who have not yet started this important work in their own communities.

Since Dr. Lambert cannot possibly cover all phases of this important problem, it seems to me that a brief review of the progress which has led to the present advanced state of affairs in upper-extremity amputations and prostheses would be of interest.

The extension in this country of medical and rehabilitation services to children, as well as adults and the expansion of crippled children's services and vocational rehabilitation in all of the states has paved the way for greater benefits to all those who are in need of surgery and prostheses for amputations of the upper as well as the lower extremities.

It was in the latter part of the second world war that the Advisory Committee on Artificial Limbs (then called the Committee on Prosthetic Devices) of the National Research Council was organized and went to work. The results of research and development carried on by the workers of the Committee, added to the experience gained in the amputation centers of the armed services during the war, resulted in vast, far-reaching and long-lasting improvements in the surgery of amputations, in the design, structure, and application of the prostheses, and in the training of the amputees. The improvements brought about in upper-extremity amputations and prostheses during the decade from 1943 to 1953 have been unparalleled in a similar period of time in history. (*Continued on page 431*)

Immobilization With Resin-Impregnated Plaster Bandages

BY JAMES DRENNAN LOWELL, M.D., BOSTON, MASSACHUSETTS

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Plaster-cast immobilization in the treatment of children presents problems not regularly encountered in adults. Unless critically ill, they are active and often do not take care of their casts even when old enough to appreciate the reasons for application. Infants may break them against crib sides or soil and soften them with urine. Others, resentful of restriction, may attempt to break them. For these reasons, we constantly hunt for new and more nearly ideal materials for cast manufacture. Partial solution of the problem has been obtained with the use of water-resistant coatings, both liquids painted directly on the plaster and plastic impregnated materials wound onto the casts and bonded there with a solvent. As these can be tedious and time-consuming to use, we were interested in testing the resin-impregnated plaster bandages when they appeared on the market. For convenience the material used in these tests will be referred to as "resin-plaster" as distinguished from plain plaster-of-Paris.

The physical properties and general characteristics of this material have been reported elsewhere in some detail [1]. Briefly, it is a combination of plaster-of-Paris, resin, and a catalyst already applied to crinoline so that it needs only wetting in water to be used. It is intended by the manufacturer that this will form a cast harder than plain plaster, which therefore, can be made thinner and lighter but still stronger than plain plaster.* The resin also makes the cast more resistant to breakdown when it becomes wet, but, unlike casts with lacquer coatings, the resin-plaster cast remains porous.

In order to investigate these characteristics, as well as others of interest to the orthopaedic staff, this material was used in a wide variety of situations such as are met with in a large children's orthopaedic clinic and a poliomyelitis clinic. Splints, solid and spring-open jackets, body spicas, solid and bivalved splints for the extremities, and walking and wedging casts were used on patients ranging in age from infancy to adulthood. Participating surgeons were requested to evaluate and record ease of application, molding, and removal and were asked to rate the immobilization provided and the lasting qualities of the cast. The amount of bandage used in each case was recorded in order to make comparison with plain plaster for such factors as weight and expense. They were asked to record any reactions or other pertinent observations. Fairly complete information was thus obtained on the use of this material in 118 casts on seventy-nine patients.

Resin-plaster exhibited some interesting characteristics which, to our knowledge, have not been previously reported. Considerable variation in the temperature of the water into which the bandage is dipped may be used to vary the setting time of plain plaster. Resin-plaster cracked and laminated frequently if dipped into water warmer than tepid. Its setting time was slower than that of plain plaster, usually about six to eight minutes. This presented a problem with infants who were constantly squirming. It was also harder to mold than plain plaster as the prolonged setting time meant that the surgeon must hold the part to be immobilized that much longer. Even after initial setting, the cast remained resilient for a few minutes more, both to the pressure of the

* The material used for these tests is manufactured by Davis and Geck, Inc., a unit of American Cyanamid Company.

surgeon's hands and fingers on the outside and to the corrected part within. If the material was rubbed too firmly and too frequently in obtaining a mold, the setting time was further delayed. If the cast were immediately bivalved with a plaster knife, lamination and cracking seemed to be more frequent than with plain plaster.

These disadvantages were offset by two unique properties. First, the laminated or cracked casts tended to "heal" in about an hour and appeared to be as strong as in the undamaged portions. Second, resin-plaster is highly adhesive and when plain plaster was used for the first layers of a cast to obtain its qualities of rapid setting and easy molding, resin-plaster would bind to it securely and add the advantages of greater strength and longer life. Resin-plaster not only bonded well to fresh plain plaster but also to dry casts of either resin-plaster or plain plaster. This was most helpful in repairing casts in which cracks had occurred or in casts to which it was desirable for any reason to add more strength. This adhesive property also made resin-plaster very useful when applying spreader bars, hinges, turnbuckles, or walkers.

The amount of resin-plaster used varied from about one-half to two-thirds that of plain plaster per cast. As its cost is more than that of plain plaster, the total initial cost of the casts was about the same for either material. However, the resin-plaster casts were lighter, they lasted longer, and were more resistant to staining and softening.

Results with long-term casts, and with several children known from past experience to be especially hard on casts, gave ample evidence of the wearing quality of the resin-plaster casts. Although thin, they stood up well under hard wear, even when frequently wet with urine. For the child who must be immobilized for a long period, this quality greatly reduced the frequency of replacement. The relative lightness was also advantageous because it was easier for the mother or nurse to handle the child, and easier for the ambulant patient to keep active.

The removal of resin-plaster casts is about as difficult as that of plain plaster casts if done immediately after setting before the cast is dry. Once dried it is harder to split resin-plaster than plain plaster with an oscillating saw or hand cast-cutter. More caution must be taken with the saw to avoid heating the plaster and burning the patient. One parent accustomed to soaking plain plaster casts off a club-footed child in about twenty minutes found it took about an hour with a resin-plaster cast.

In none of the seventy-nine consecutive patients treated did sensitivity reactions develop. However, a skin rash developed in one surgeon repeatedly when in contact with the resin; and, since the study was completed, in four patients (here in non-consecutive instances) skin rashes have also developed, of which two were severe but not generalized. This, therefore, is at least an occasional problem in the use of this material.

Since experience has indicated that the use of resin-plaster is better suited to certain types of casts than to others, a detailed discussion of its use in several major groups of cases is of interest.

Club-Foot

Thirty-eight casts were applied to twenty-two patients with club-foot. The patients ranged in age from three months to ten years. The majority of the casts were applied from the toes to the groin. A number of these were immediately split, lined, and used as bivalved casts. Others were wedged, some as many as three times. It was with this group of casts that the difficulty of obtaining a good mold with resin-plaster became apparent. However, the solution, involving the use of plain plaster for the first layers, was very satisfactory, and permitted repeated wedgings for some children for whom they had not previously been possible, and prolonged the life of the cast for others.

Case 1. J. K. was a male, six years old, weighing eighty pounds. Resin-plaster (four six-inch rolls) was applied over plaster on bilateral toe-to-groin casts on August 3, 1954. Application, molding, and im-

mobilization were rated *excellent*. Lasting qualities were rated *good* with this comment: "This boy is 'wild'. Surprisingly the casts are in good condition two weeks after application when seen in the Out-Patient Department for wedging." On August 24, 1954, the cast was in good condition. On September 1, 1954, it was very good after repeated wedgings. None of many previous casts on this boy had lasted more than two weeks.

CASE 2. D. H. was a male, six months old, weighing twenty pounds, with metatarsus varus. A cast for the left lower extremity was made for which three two-inch and two three-inch rolls of resin-plaster were used. Although molding was good, application is rated as *poor*, with the comment: "did not harden quickly enough. Child kicked knee apart." This damage was repaired with resin-plaster, and the lasting qualities were reported as *excellent*. "Cast wet with urine without detriment; lasted well."

The second case also illustrated how a damaged cast can be mended without losing its strength.

In general, favorable results were obtained with this group. We do not now use resin-plaster for the initial layers of a cast, especially for the youngest children, when rapid setting is of importance if a good mold is to be obtained. But, since it is this same group of children who will break down plain plaster casts rapidly because they knock them against crib sides and wet them with urine, we found resin-plaster as a covering to be a distinct advantage in helping to cut down the unfortunate consequences of these two common problems.

Poliomyelitis

Twenty-nine casts were made for twenty-two patients in this group. About one-half of these casts were bivalved casts and were used as adjuncts to prevent the acquirement of deformity in early and late cases with asymmetrical muscle involvement or tightness. The remainder were solid or wedging casts used to overcome deformity already acquired. Immobilization was rated *excellent* in twenty instances, *good* in six, *fair* in one case. Two were not evaluated. Lasting qualities were rated *excellent* in nineteen, *good* in six, and *fair* in three cases. One was not evaluated. Several of the casts had been in use two or more months at the time of writing. One bivalved cast was fitted with a heel with *good* lasting qualities. The five-year-old patient eventually broke the posterior half by pushing himself with the leg in a "go-cart". In another case resin-plaster was used to wedge a plain cast with *excellent* results.

Since support in poliomyelitis is often a long-term matter, the wearing quality of resin-plaster made it a good choice for these patients. It can be bivalved easily when fresh. Although one surgeon reported rather frequent lamination when so doing, it did not appear to affect the subsequent strength of these casts. The wearing qualities in reports noting lamination were almost always rated *excellent*. Since most of the patients in this group were older than the patients with club-foot and hence more cooperative, the prolonged setting time of resin-plaster was not a significant problem.

Scoliosis

Five patients with scoliosis were included in this study and a total of seven jackets were applied. Five of the jackets were body spicas of the Risser type including one arm and the opposite leg and were used in conjunction with turnbuckles and hinges to correct deformity both before and after operation. The other two jackets were molded body jackets, one of the "spring open" type, and one of the solid type that included the torso only. They were used late in the postoperative care to help retain correction obtained previously.

CASE 1. G. M., a female, thirteen years old, five feet, four inches tall, weighing 130 pounds. A Risser spica was applied to one knee and to the opposite elbow on April 28, 1954, which required three three-inch and twelve four-inch rolls of resin-plaster. Application, including hinges and turnbuckles, was rated *excellent*, as was molding and immobilization. Permeability to x-ray was good. Lasting qualities were *excellent*. It was removed for surgery and a new spica was applied on June 21, 1954. The postoperative spica was still in use five months later.

Case 2. K. O., a female, sixteen years old, five feet, four inches tall, weighing 102 pounds. A solid body jacket, encasing the trunk only, was made of four four-inch rolls of resin-plaster. The comment was: "Cast cracked three inches over left iliac crest but did not need repair. Lasting qualities: *excellent*. X-ray permeability: *excellent*."

Although total experience is limited in this group, the results indicate that this may be one of the more promising uses of resin-plaster. Jackets, especially spicas, of one-half to two-thirds the amount and weight of plaster, but of greater strength, were made with resin-plaster. It was considerably easier to care for these children and one of the great advantages was the increased permeability of these spicas to x-ray. Accurate vizualization of the vertebral bodies in the area of maximum curve is always difficult as these vertebrae are often the ones directly overlayed by the hinges and the extra plaster used to attach them. Visualization of the vertebral bodies in all the resin-plaster spicas was rated *good* to *excellent* except in one case where it was rated *fair*. This patient was a seventeen-year-old, 170-pound male who required an "extra heavy jacket" even of resin-plaster.

We have been accustomed to using spring-open jackets of plastic laminate to support the trunk beginning about six months after fusion. These are made over a plaster form of the patient and require considerable time, effort, and expense. One spring-open jacket of resin-plaster made directly on the patient has been tried and rated *excellent*. Further evaluation of this method is being undertaken.

Other Conditions

For two patients with hemophilia, removable splints of resin-plaster were made to protect joints involved by hemarthrosis. In each instance, the splints, though light, worked well and the lasting qualities were rated *excellent*. One twelve-year-old boy, five feet, four inches tall, weighing 120 pounds, received a one and one-half bivalved spica of resin-plaster to immobilize a femur with osteomyelitis. Two months later this cast was in excellent condition. A girl fifteen years old, five feet, ten inches tall, weighing 165 pounds, was given first one, then a second cylinder of resin-plaster to protect a knee with osteochondritis dissecans. In each instance the lasting qualities were rated *fair* when the casts lasted only eight and six weeks respectively. A two-year-old female infant with a congenital dislocation of the hip was given a bilateral short leg-hip spica of plain plaster covered with two four-inch rolls of resin-plaster. Although it was stained with urine, the cast stood firm four weeks later.

CONCLUSIONS

In our experience resin-plaster bandage has proven a convenient and useful material for many casts for both children and adults. It is most satisfactory for large casts that must be worn for long periods and must have maximum x-ray permeability, such as, body jackets and body spicas used in the treatment of scoliosis; for casts that may become wet, such as club-foot casts and hip spicas in infants; or wherever a combination of lightness and strength is desirable. Resin-plaster bandage made strong splints and bivalve casts that usually survived even on the most active children. Resin-plaster was not as satisfactory as plain plaster for the initial layers of casts requiring rapid setting and considerable molding such as club-foot casts for infants. When used for the finishing layers, once a mold was obtained, it proved a most useful adjunct to the treatment. In the seventy-nine consecutive cases studied no skin reactions were reported. However, as noted previously, one doctor and subsequently four patients in non-consecutive instances developed skin rashes when in contact with the material.

SUMMARY

The performance of a resin-impregnated cast material has been studied in seventy-

nine patients representing 118 applications. This material is a ready-to-use bandage of plaster-of-Paris, resin, and catalyst, bonded to crinoline.

Characteristics in which this material differs from plain plaster are discussed. It is water-resistant and stands up well under hard wear. Its initial setting time is slower than that of plaster; it is more difficult to mold and to remove when dry. A unique property is its ability to "heal" after cracking or laminating, apparently without losing either its strength or its wearing quality. Specific problems for which the material was used are discussed and illustrative cases are presented.

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DISCUSSION

Upper-Extremity Prostheses in Juvenile Amputees

(Continued from page 426)

In 1949, the Veterans Administration established special orthopaedic clinics for the care and supervision of all amputees who were beneficiaries of that organization,—one of the most important steps ever taken in the country to properly organize and administer a medically supervised service for amputees on a large scale.

Finally, a few years ago, an organized course of instruction was set up under the direction and supervision of the Advisory Committee on Artificial Limbs and the Veterans Administration at the University of California at Los Angeles. Teams of physicians, therapists, and prosthetists have been sent there for training in the care of the patient with an upper-extremity amputation, including the details of prescription, the fabrication and fitting of the prosthesis and training of the upper-extremity amputee.

A sufficient number of courses have been given at the University of California at Los Angeles, so that every section of the country now has representatives who were sent there to be trained.

As he has pointed out, Dr. Lambert also is a recipient of this course, and what he and his team have done is to be greatly admired by all of those interested in the problem of upper-extremity amputations. Their work should serve as a stimulus and an inspiration to those who are in a position to further this work in their own communities, and as a wonderful example of what can be done for the juvenile amputee.

Dr. Harold E. Crowe, Los Angeles, California: We all know that in amputations performed on children, especially in those below-the-knee, the tibial stump will assume a spike-like configuration and ultimately the tip of the stump breaks down so that reamputation will be required. This is true even though the tip of the tibia is covered with a normal layer of skin and subcutaneous fat with the scar placed well behind the tip of the stump. Two questions have troubled me for many years. If there is a breakdown of the stump after an amputation performed on a child, (1) is it because the bone continues growing out through the end of the soft-tissue stump, or (2) is it because the bursa which develops on the tip of the bone becomes infected secondarily and then breaks down, giving the false impression that the bone did grow through the soft-tissue? Which is true, Dr. Lambert?

Dr. Lambert (closing): This question has come up repeatedly, and, as I mentioned in the paper, some surgeons have advocated not putting a prosthesis on the child until he has stopped growing, lest it might be necessary to perform a reamputation. In the first place, if there has been a good amputation, without scar tissue over the end of the bone and with a well padded stump, there is very little likelihood that the bone will grow out through the stump. However, if there has been a poor amputation, and if a lot of periosteum has been left protruding, the bone may grow out. In a well done amputation, there is relatively little chance that reamputation will have to be done. Again, should it happen that a reamputation must be performed, it is no contra-indication to giving the child a prosthesis at an early age.

Letter to the Editor

To the Editor:

The preparation of a comprehensive *Dictionary of Braces* or *Orthopedic Appliance Reference Manual* has been authorized by the Orthopedic Appliance and Limb Manufacturers Association, in cooperation with the American Board for Certification. The Association has provided an appropriation of $3,000 toward the initial cost of such a reference work.

The need for such a reference manual to be used in the brace shops of the country is indicated by the confusion in terminology which exists. Speaking on this point, W. Frank Harmon, President of the Orthopedic Appliance and Limb Manufacturers Association, said:

"It has been proposed that we produce a Brace Dictionary or Encyclopedia that would properly identify orthopedic appliances with correct terminology and nomenclature in order to eliminate some of the confusion that has existed in different sections of the country as a result of incorrect terminology and nomenclature, as well as the use of individuals' names used to describe appliances.

"A typical example is a brace that is being discussed at length in one of our seminars at this Assembly by Dr. A. C. Schmidt and Richard Bidwell, The Milwaukee Brace. In so far as I have been able to learn, the Milwaukee Brace originated in the House of Bidwell with the assistance and guidance of Dr. Walter Blount and Dr. Albert Schmidt of Milwaukee. In 1945, while with the Warm Springs Foundation, Dr. Charles E. Irwin, then Chief Surgeon and Medical Director, became interested in this appliance after hearing it discussed at a meeting of orthopedic surgeons.

"Dr. Irwin requested and received from Dr. Blount a photograph and description of this brace and proceeded to have it duplicated in the Warm Springs Brace Shop where it became known as the Blount Frame. Within a few months, however, numerous changes had been made so that soon the brace took on characteristics that had little resemblance to the model originally used.

"By way of explanation, the Milwaukee Brace or the Blount Frame were intended for identical purposes: (1) conservative treatment and correction of cervico-thoracic spine curvatures, and (2) as a post-operative appliance to hold spine fusions of the same area during the convalescent period. The finished Milwaukee Brace is shown on pages 232 and 233 of the *Orthopaedic Appliances Atlas*, while the Warm Springs modifications are illustrated on pages 504 and 505. The finished appliances bear very little resemblance to each other.

"A Brace Dictionary could do an excellent job in identifying and distinguishing these braces with cross references and reference to the *Orthopaedic Appliances Atlas* for more detail.

"A second instance has recently come to my attention in which a brace dictionary would be valuable. The term 'fenestrated thigh cuff' is currently used in connection with the practical performance test for orthotists. In twenty-two years of practical experience in making and fitting braces I had never heard of the term and as of this writing I am still somewhat uncertain of its intended meaning. A glossary would clarify this term. . . ."

Matt Laurence, Certified Orthotist and Prosthetist of Oakland, California, is serving as Chairman of the Committee in charge of the Brace Dictionary Project. Suggestions on the content of the Dictionary should be addressed to him in care of the American Board for Certification, 1145 19th Street, N. W., Washington 6, D. C. The Committee is especially interested in learning of any lists of nomenclature which may have been compiled by readers of *The Journal of Bone and Joint Surgery*.

While the final form of the Dictionary has not been definitely determined, the present plan is to list in alphabetical order every known brace and brace part. Each part would be cross-referenced and indexed with respect to that portion of the anatomy to which it would apply.

Construction details would be omitted in so far as possible with every effort being made to encourage the use of the Volume I of the *Orthopaedic Appliances Atlas* whenever possible by giving reference to page number and illustration number in the *Atlas*.

Alphabetical listings would be accompanied by line drawings where indicated, in order to illustrate essential details. Unnecessary details of little consequence would be eliminated.

Anatomical names, terms, and expressions in common and accepted usage would be listed, defined, and illustrated wherever practical.

It is hoped to provide blank pages for additions by the user in order to keep the manual or dictionary current.

Lester A. Smith
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Prosthetic and Orthopedic Appliance Industry, Inc.
Washington 6, D. C.

Proceedings

WESTERN ORTHOPEDIC ASSOCIATION

Prepared by the Editorial Committee of the Western Orthopedic Association: J. Vernon Luck, M.D., *Chairman;* K. O. Haldeman, M.D.; George L. Dixon, M.D.; Kirk J. Anderson, M.D.; and Robert D. Ray, M.D.

The Nineteenth Annual Meeting of the Western Orthopedic Association was held in Honolulu, Hawaii, at the Reef Hotel, November 6 to 10, 1955. From the Association's twelve chapters, located in the western states and Hawaii, came many members with their wives and guests. The mornings were devoted to the scientific program, while the afternoons and evenings were left free for the delightful social activities that had been arranged by the Honolulu Chapter. Dr. J. Warren White ably presided.

The high points in the social schedule included an impressive Luau (native feast) held at the Queen's Surf, and a formal banquet-dance held at the Reef Hotel. At the latter Dr. Nils P. Larsen presented a colorful motion-picture pageant entitled "Birth and Growth of Surgery in the Pacific". Among other activities arranged were tours of the Islands, of Pearl Harbor, and of the Tripler General Hospital.

Dr. James Lytton-Smith was installed as the next president; he will preside at the 1956 meeting, which is to be held in Phoenix, Arizona. The other officers elected were as follows:

President-Elect: Samuel S. Mathews, M.D., Los Angeles, California;
Vice-President: Robert Hastings, M.D., Tucson, Arizona;
Secretary: John Reker, M.D., Phoenix, Arizona;
Treasurer: George Williamson, M.D., Phoenix, Arizona;
Librarian and Historian: Harry R. Walker, M.D., Oakland, California;
Editorial Committee (New Member): Robert Mazet, M.D., Los Angeles, California.

The Residents' Program was excellent and was well received. The following Vernon P. Thompson Awards were given for the best resident papers. A first award of $300.00 went to Dr. Sherman S. Coleman. In second place, Dr. Ralph Pietrobono and Dr. L. Ward Wiseman were tied, and each received an award of $200.00. Dr. W. J. Treanor, a physiatrist, received an honorarium of $100.00. The Thompson awards are given only to orthopaedic residents; the winners attend the meeting as guests of the Association.

The Articles of Incorporation of the Western Orthopedic Association were read by Dr. Harry Walker and were adopted by the Members.

Monday, November 7, 1955

Electromyography in Normal and Transplanted Muscles in the Lower Extremity. Dr. Bret W. Smart [1], Dr. John A. Blosser [2], and Dr. J. Robert Close [3] presented, by means of a sixteen-millimeter film, a combined visual and auditory record of the muscle action of subjects as they walked or contracted their muscles voluntarily. The study was confined to the muscles of the lower extremity, and the film showed both normal subjects and subjects in whom tendon transfers had been performed following poliomyelitis. The method used in this study was as follows. Two wire electrodes were inserted into each muscle of the lower extremity, and leads were run from these electrodes to the electromyograph and thence to the sound camera. Before and after each test, the positions of the electrodes were checked by means of electrical stimulation. The sound track that resulted from this procedure presented the normal auditory record of the electromyograph as heard through a loud speaker.

Various groups of subjects were observed in this study. In normal subjects the action of the gastrocnemius, soleus, peronaeus longus, and biceps femoris was studied. Five patients were shown in whom postpoliomyelitic peroneal-tendon transfers to the front of the foot had been done. In all of these patients, the primary-stance-phase activity of the peronaeus longus had been retained, and in three of these patients some swing-phase activity had been acquired. In five patients in whom the peronaeus longus insertion had been transferred to the heel cord or calcaneus the muscle's normal-stance-phase activity had been retained. In two of these patients, however, the transferred muscle demonstrated little activity during motion, except when the patient was walking in an exaggerated manner or was standing on the toes. One patient in whom the insertion of the extensor hallucis longus had been transferred to the first metatarsal showed no change in the swing-phase activity of the muscle. Three patients were studied in whom the insertion of the biceps femoris had been transferred to the patella. In one of these patients there was only a moderate amount of paralysis in the involved extremity and the swing-phase activity of the transferred muscle had been retained. In the two

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other patients there had been considerable paralysis in the involved extremity; in these patients the activity of the muscle throughout both phases of the walking cycle was studied.

This study does not lead to any definite conclusions concerning the phasic conversion of muscles with transferred tendinous insertions. It does demonstrate, however, that when a muscle is thrown "out of phase", that is, when it cannot act during the phase in which it normally acts because of transplantation, there is an attempt by the neuromuscular system to acquire additional activity during the affected phase in order to replace the activity of the transferred muscle.

Anteversion and Walking Cast in Congenital Dysplasia of the Hip. Dr. Eldon G. Chuinard [4] presented a fifteen-minute film on the treatment of congenital dislocation of the hip in patients over the age of infancy. The treatment shown was that routinely used at the Shriners' Hospital for Crippled Children in Portland, Oregon.

The film showed a patient with a dislocated hip being treated in the routine manner; each stage in the routine was clearly demonstrated. The technique for the determination of anteversion by means of roentgenograms was presented, and a roentgenogram of the femur in the position of abduction and medial rotation was shown. In this roentgenogram, the view of the head and neck of the femur was anterior and the view of the supracondylar portion was lateral. Other aspects of the treatment shown were the application of a hip spica, this spica being used to maintain the femur in the position of medial rotation, and the inclusion of a walking peg. Several patients in casts, including two in bilateral casts, were shown walking. After the patient had been walking in the cast for six months, a derotation subtrochanteric osteotomy was carried out, the cut being made between Steinmann pins.

The following conclusions may be derived from this study:

1. Skeletal traction and derotation osteotomy have not been used to treat congenital dislocation of the hip as often as they should. Their use has become more frequent, however, since the author's method of treatment was developed.

2. There is no correlation between the acetabular index and the final results.

3. The presence of an uncorrected abnormal anteversion does not adversely affect the final results.

4. Correction of the anteversion by means of an osteotomy will obviate open reduction.

5. The correction of the anteversion should be done before either a turn-down shelf operation or an intra-articular procedure is done.

6. There is no specific degree of anteversion which in all cases constitutes a clear indication for the performance of a derotation osteotomy. The younger the child, the more likely it is that "natural growth processes" will correct the anteversion. Any doubt should be resolved in favor of doing an osteotomy, however, and in the author's opinion the presence of 30 degrees of anteversion is, in most cases, an indication that a derotation osteotomy should be done.

7. It is the author's belief that the subtrochanteric area is the proper site for the performance of a derotation osteotomy.

8. The use of a walking cast after reduction does not appear to increase the incidence of aseptic necrosis in the femoral head.

Volkmann's Ischaemic Contracture: *Its Cause and Prevention.* Dr. Paul R. Lipscomb [5] had reviewed the records of ninety-two patients with Volkmann's ischaemic contracture of the upper extremity. The patients whose records were reviewed had been seen at the Mayo Clinic between 1934 and 1954. With the knowledge available twenty years ago, it had been thought possible to prevent the development of the process in only thirty-eight of the ninety-two cases. With the knowledge available today, it would be possible to prevent the disease in at least sixty-one of the ninety-two cases.

On the basis of his review and on the basis of his experience with ten patients, Dr. Lipscomb had come to the following conclusions concerning the cause and prevention of Volkmann's ischaemic contracture. (The ten patients seen by Dr. Lipscomb had come to him within one to seventy-two hours after sustaining an injury and had undergone arteriectomy because of irreparable damage to the brachial artery at the level of the elbow and in some cases because of impending Volkmann's ischaemic contracture.) Dr. Lipscomb felt that the most important cause of Volkmann's contracture is spasm of the arterial tree in the injured extremity. He claimed that if relief from the spasm is not immediately obtained after all external compression has been removed, the spasm can often be eliminated by early resection of the injured or thrombotic segment of the brachial artery. The presence of an injury to the brachial artery is quite common after the occurrence of some injury about the elbow, including a fracture in the supracondylar area.

If the spasm develops following a compound injury or following a severe crushing and contusion injury of the forearm, Dr. Lipscomb felt that relief could be best obtained by the prevention or release of intrinsic as well as external compression. This objective can be accomplished not only by the removal of tight casts and

[4] 1922 N.W. Johnson Street, Portland, Oregon.
[5] Mayo Clinic, Rochester, Minnesota.

dressings, but also by the extension of the original wound and by the relaxation of the incisions. At the time of such surgery the radial, ulnar, and lower brachial arteries should be inspected, and removal of an irreparably damaged segment of these vessels should be performed.

In patients in whom an upper-extremity artery has been so damaged that it is incapable of transmitting blood, it is less hazardous to excise a segment of the artery than it is to leave the artery as it is.

Physiological Implications of Abdominal Fascial Transplants. Dr. C. L. Lowman [6] claimed that when an acute poliomyelitic attack is associated with respiratory, circulatory, and eliminatory deficiencies, operative intervention, in the form of abdominal fascial transplants, frequently becomes necessary three or four months after the attack.

As a result of the poliomyelitic attack, the neuromotor and skeletal factors in the respiratory function are impaired, and this condition must be corrected in order that the integrity of the respiratory muscles may be preserved. One end of each muscle must be in a fixed position if the muscle is to attain maximum function, and intrinsic balance is necessary for normal postural alignment.

Rib movement is a dynamic factor in respiration. Steindler emphasized that muscle effort takes place even in quiet breathing, and it is known that respiratory changes occur as a result of variations in bodily posture. An increase in the obliquity of the ribs will cause a decrease in spring action and this will prevent normal expiratory elasticity.

The insertion of abdominal fascial transplants will produce a number of benefits. The vital capacity will be increased up to 1,000 cubic centimeters, and stabilization of the thorax will be achieved. By means of attaching healthy abdominal muscles to the pelvic or costal margin or from the pelvis to the rib margin, the intercostal and diaphragmatic function will be improved, and it has been consistently recorded that the insertion of transplants results in improvement in the circulation of the extremities and lower torso.

In his discussion of this paper, Dr. J. Vernon Luck [7] concurred with Dr. Lowman's opinion concerning the physiological benefits that may be derived from the use of abdominal fascial transplants. He emphasized that the position of the lumbar portion of the spine must be taken into consideration when the tension of the fascial straps is established. If there is a lordosis of this portion of the spine, the table should be bent in order to flatten the spine. On the other hand, if the lumbar portion is already flat, care should be taken not to increase the amount of flexion that is present, for increased flexion would force the patient into a bent-forward posture. Dr. Luck stressed that a proper program of postoperative care is as important as the operative technique itself and mentioned that the psychological benefit derived from this operation is frequently great. At the conclusion of his discussion Dr. Luck emphasized the importance of carrying out the procedure as early as possible in order to prevent the occurrence of contractures and other undesirable complications which might be caused by delay. As is true of patients with severe arthritis, patients with severe paralysis frequently derive great benefit from improvements which, from the kinetic standpoint, might appear to be relatively minor.

Osteography of the Femoral Head. Dr. Floyd Jergesen [8] presented a preliminary report on the use of osteography (osteovenography, medullography, or medullophlebography) as a means of estimating the vascularity and viability of the head of the femur. In this study a solution of 50 per cent sodium diatrizoate had been injected into the proximal portion of the femur, the acetabulum, or the ilium in twenty-five individuals; the pattern of distribution and the manner and rate of removal of this solution had then been recorded roentgenographically.

In fifty hip joints, twenty-five normal and twenty-five with pathological conditions, sixty-six examinations had been made by the rapid injection of from two to fifteen cubic centimeters of the medium. General patterns of venous filling had been demonstrated, these patterns varying according to the volume of medium used and according to the location of the injection. In the normal hip-joint the medium disappeared completely from the venous system within five minutes and disappeared almost completely from the bone within fifteen minutes. In the hip joints with pathological conditions, however, there had been a comparative failure to show venous filling and a comparative delay in removal of the medium from the bone, suggesting the presence of a disturbance in vascularity. The pathological conditions present in the hips investigated had included cervical fracture, intertrochanteric fracture, traumatic dislocation, degenerative arthritis, rheumatoid arthritis, septic arthritis, avascular necrosis, epiphysiolysis, and secondary bone atrophy.

The contra-indications observed in this study had been those customarily observed in any procedure involving the use of iodine-radiograph media. No complications or major reactions had occurred in the study, and there had been no evidence of toxicity due to sodium diatrizoate. Acute pain had been caused by the rapid injection of volumes greater than three cubic centimeters, necessitating the use of a general or spinal anaesthesia.

[6] 2417 South Hope Street, Los Angeles, California.
[7] 1930 Wilshire Boulevard, Los Angeles, California.
[8] 384 Post Street, San Francisco 8, California.

As a result of extravasation into either the soft tissues or into the hip-joint cavity, a number of examinations had been unsatisfactory. Technical errors had also caused failures, and other factors that might have had adverse effects were the presence of a dense trabecular structure, the presence of a broad epiphyseal scar, and, possibly, the presence of poorly vascularized, fatty marrow. In ten of the cases in which the examination had been unsatisfactory, the epiphyseal portion of the head had been involved.

No conclusion was reached in this study concerning the ultimate clinical value of osteography as a means of examining the head of the femur. Although the preliminary results obtained are indicative, final judgment should be reserved until further experience is available. It should be remembered that the performance of osteography is not without hazard.

Orthopaedic Consideration of Agammaglobulinaemia in Two Full Blood Brothers. Dr. Dellivan M. Fuiks [9] and Dr. William Bittner [10] had originally planned to present a paper on hydrops of the knee in a patient with agammaglobulinaemia. While they were observing the progress of their patient, however, a younger brother had presented himself with a severe case of septic arthritis and, on investigation, it had proved that he too suffered from agammaglobulinaemia. As a result of this circumstance, the authors had decided to change the subject of their paper and to present what they believed was the first report of the occurrence of agammaglobulinaemia in two children of the same family. To the best of their knowledge, this report is also the first orthopaedic study ever made of this unusual serum-protein deficiency.

Serum-protein determinations may now be made easily and economically by means of filter-paper electrophoresis. These electrophoretic studies are of value and interest in the diagnosis of previously undiagnosed cases of hydrops of the joint. To obtain recoveries in patients with congenital agammaglobulinaemia, maintenance dosages of immune gamma globulin are necessary.

In his discussion of this paper, Dr. A. B. Sirbu [11] emphasized that a diagnosis of hypogammaglobulinaemia should be considered for all cases in which infants with severe bone or joint infections fail to respond to antibiotic therapy. Many such infants will have a gamma-globulin defect and will respond only to adequate gamma-globulin therapy. Dr. Sirbu praised Dr. Fuik's work and urged a wider use of the simple test described in his paper.

Tuesday, November 8, 1955

Symposium on Low-Back Pain

Dr. Joseph C. Risser [12] felt that the increasing frequency of low-back pain makes it necessary to find a conservative treatment that will be adequate for the majority of cases. This treatment should be directed toward the prevention of the condition as well as toward the obtaining of relief. In the past, many of the conservative regimens that had been tried had failed and, as a result, many patients had had to undergo treatment by surgery — by disc removal or spine fusion.

During the past twenty years recumbent postural exercises have been highly successful in providing relief of pain, especially in cases in which there is pain referable to the leg or in which other signs of nerve pressure are present. The rationale for this program is based on the fact that improvement in the physiological processes of a joint occurs when the range of motion of the joint is complete. The joint cartilage obtains most of its nourishment by means of imbibition or "sucking in", a process which depends upon the application and release of pressure and which thus occurs best in a joint with complete motion. Furthermore, the presence of a complete range of motion results in stretching of the joint, and stretching encourages relaxation.

The theory behind this type of therapy can perhaps be further described by an explanation of the derivation of the word *exercise*. *Exercise* comes from the Latin words *ex* — from — and *arcere* — an enclosure. Thus, to "stretch out the joint contracture" is a literal interpretation of the word. A practical example of how this therapy operates is as follows: by means of exercise, the hamstrings are stretched; this stretching permits greater motion of the hip, and this greater motion of the hip, in turn, removes some of the stress from the lower portion of the back.

In order that much of the strain of gravity will be eliminated, the exercises are in the main performed with the patient lying down.

The exercises are designed to improve the patient's posture, for by lessening the lordotic arcs, they relieve the shearing stress on the lumbosacral portion of the spine.

The exercises should be done slowly, with periods of rest. Too often they are done rapidly, the stretch factor being ignored, and the patient thus deriving little benefit from the therapy.

Except in acute cases, the patient begins his treatment with the exercises, the simpler ones being done first. In the acute cases, heat, massage, and rest are used first and are then followed in a day or two by the exercises. This conservative regimen will eliminate low-back pain in many patients who would otherwise require surgery.

[9] 820 24th Street, Sacramento 16, California.
[10] Sacramento, California.
[11] 450 Sutter Street, San Francisco 8, California.
[12] 2637 E. Washington, Pasadena 8, California.

Structural Localization of Back Pain. Dr. Robert L. Garrett [13] reported his experience with the clinical application of irritative-tissue techniques in cases of peripheral low-back tenderness. His work was based on the observations of Kellgren and Inman.

Dr. Garrett stated that myoneural tenderness tests, when applied to specific groups of muscles, are useful in the localization of disc lesions and in the determination of the possibility of a recovery being obtained by conservative or surgical treatment. The tests are usually performed by means of simple massage.

After correlating the presence of disc lesions (diagnosed by discographic study) with his clinical findings and operative results, Dr. Garrett had concluded that low-back pain originates primarily in the osseous attachments of the posterior longitudinal ligament and that this pain is caused by a pathological disc condition rather than by root compression, as had been believed in the past. It was noted that among forty-two cases in which laminectomies had been performed, there had been eight cases in which two discs had been involved and one case in which three discs had been involved.

It was concluded that by application of the myoneural-tenderness test and by judicious use of discographic studies, a better understanding and management of back problems could be obtained.

Dr. Beckett Howorth [14] reported that there are two main ways in which low-back pain may occur: (1) it may arise within the musculoskeletal structure of the lower back or within the nerve and nerve roots which supply that area, or (2) it may be related to an acute general disease or to a disease of the pelvic or abdominal organs. If it is related to a pelvic or abdominal disease, there will be other symptoms or signs which refer to the disease and the results of an examination of the back will be negative. In these cases the choice of treatment should depend upon the other indications rather than upon the presence of back pain.

The backache which arises within the structures of the back may be due (1) to anatomical faults in the bones or joints or in the muscles and ligaments, especially those of the lumbosacral joints; (2) to the strains caused by poor posture, pregnancy, or obesity; or (3) to stresses produced by the environment. A poor bed, a bad car seat, and a badly fitting pair of shoes are examples of environmental factors which may cause stress. Strain may also be produced as a result of occupational activities, hobbies, or participation in sports. The structural bone abnormalities which most commonly cause backache are deformities of the articulations, the presence of a transitional lumbosacral joint, an acute lumbosacral angle, spina bifida, and spondylolisthesis. The most common degenerative lesion is extrusion of the nucleus pulposus.

The intelligent and effective treatment of low-back pain requires that all the above factors, including the environment and activity of the patient, be taken into consideration. In more than 95 per cent of cases, backache can be relieved without surgery, the main exceptions being those cases in which spondylolisthesis is present or in which there is extrusion of the nucleus pulposus.

The basic treatment of low-back pain should include the following: the provision of a firm flat bed, proper chairs, and proper shoes and clothing; correction of posture or reduction in weight where indicated; rest or support, at least in the more severe or persistent cases; and special exercises and training in dynamic posture. Heat in various forms and massage may be used to obtain initial and temporary relief, but these measures should not constitute the only treatment, and they should not be unduly prolonged. On a long-term basis, exercises for the trunk muscles and training in the proper use of the body are the most valuable types of treatment; for these types of treatment, however, training, intelligence, and careful and persistent application are required.

Dr. Steele F. Stewart [15], in closing the symposium, pointed out that the spine is made up of a series of levers. To these levers are attached ligaments which function as restrainers to prevent the occurrence of any unlimited motion. Multiple fulcrums and motors are present.

Fish were the first vertebrates to have a spinal curve. This curve was dorsal, and it developed in order that the viscera might be protected.

The first cervical spinal curve occurred in the snake; as a result of this curve the snake's radar mechanism and its eyes and ears could be brought into a more advantageous position.

The sacral curve first developed in mammals. This curve serves to protect the organs of regeneration. The lumbar curve is found only in humans, and it developed as a result of the assumption of an erect position.

In his discussion Dr. Stewart summarized a number of the points made in the previous papers. He particularly emphasized the fact that the injection of novocain into trigger points of tenderness may be used both as a therapeutic measure and as a diagnostic procedure. He stressed the importance of pre-employment examinations and pointed out that in the Hawaiian Islands this procedure had been widely used with great success.

The Diagnosis of Congenital Dysplasia of the Hip in the Newborn Infant. Dr. Sherman S. Coleman [16] had examined 2,500 newborn infants in an attempt to establish criteria for the diagnosis of con-

[13] 1512 Napa Street, Vallejo, California.
[14] 126 Bedford Street, Stamford, Connecticut.
[15] 1133 Punchbowl, Honolulu, Hawaii.
[16] Primary Childrens Hospital, Salt Lake City, Utah.

genital dysplasia of the hip in infants who have just been born. He expressed the belief, that, provided a careful examination is made, the diagnosis can almost always be made at birth or shortly thereafter. He admitted, however, that the customary signs of dislocation of the hip are rarely present in the newborn infant and that roentgenograms of an infant's pelvis are difficult to interpret.

Roentgenograms of the pelvis of newborn infants had been studied, and conclusions had been drawn from roentgenographic examinations of 150 infant subjects chosen at random. The need for placing the subjects in specific positions was emphasized, and a method of achieving this positioning was illustrated. The significance of the acetabular index and of the other features shown by the roentgenograms was evaluated, the possible variations in the appearance of these features being described. The possibility of correlating the clinical findings and the roentgenographic evidence for either normal hips or hips with pathological conditions in newborn infants was discussed. It was emphasized that in cases of dysplasia, greater reliance should be placed on the clinical findings than on the roentgenographic evidence.

Five criteria for establishing the diagnosis of congenital dysplasia of the hip in the newborn infant were proposed. These criteria included (1) manual displaceability of the femoral head from the acetabulum, (2) *persistent* and unequivocal limitation of abduction in the flexed thigh (a rare finding in the newborn), (3) an acetabular index of 40 degrees or more, (4) lateral disposition of the femoral neck, and (5) any combination of the above. On the basis of these criteria congenital dysplasia of the hip had been diagnosed in twenty-two of the 2,500 newborn infants examined, an incidence of slightly under 1.0 per cent.

A plea was made for the frequent examination of infants during the first year of life. Although in many cases an undetected dysplasia will correct itself spontaneously, in many other cases it will not. In these cases the mild primary changes may be accentuated through growth and in later months the more obvious secondary changes will appear. In cases of congenital hip dysplasia, treatment should be instituted as soon as the diagnosis has been made.

The Anatomy of the Cervical Region with Particular Reference to the Symptomatology of the "Whiplash" Lesion. Dr. Ralph Pietrobono [17] reported that the symptoms of the "whiplash" lesion are due to a combination of factors. Among these factors are local injury, referred pain, radiculitis, and stimulation of the sympathetic nervous system.

A soft-tissue injury may occur in the muscles, in the muscle insertions, in the ligaments, and in the other soft tissues around the intervertebral foramina. Fractures may be present.

If the injury is suboccipital, pain may radiate over the head; if the injury is between the suboccipital region and the fifth cervical disc in the posterior portion of the mid-line, pain may occur in the posterior portion of the neck and shoulders; and if the injury is below the fifth cervical disc, pain may occur in the neck, shoulders, upper portion of the back, and upper extremities.

Within the spinal canal the cervical nerves may be compressed by a herniated nucleus pulposus, and within the intervertebral foramina they may be irritated by disruption of the foramen or by local tissue reaction. Spasm of the scalene muscles may stimulate the cervical nerves by means of constriction, angulation, or compression; and disruption of the atlanto-occipital joint may involve the nerve root of the first cervical disc along with the accompanying sympathetic nerve elements.

Radiculitis may produce pain, paraesthesia, or muscle spasm. If the muscle spasm involves the suboccipital musculature, there will be an impairment in balance; if it involves the deep flexors, the spine will become straight or kyphotic. Irritation of the first or second cervical discs may cause trigeminal symptoms.

The sympathetic nervous system may be stimulated at any point between the skin and the intervertebral foramina, and the response to this stimulation may occur on any of the innervated tissue.

Any of the symptoms which occur as the result of a whiplash injury may be modified by the psychological makeup of the patient.

In this study the cervical ligaments were stained with Verhoeff's elastic stain in order that their relative elasticity might be determined. On the basis of the size and number of the elastic fibers that were found, it would appear that the ligamentum flava, the atlanto-occipital membranes, and the ligamentum nuchae are very elastic; that the supraspinous and the interspinous ligaments are somewhat elastic; and that the anterior ligaments are relatively inelastic.

Restitution of Function Following Hemiplegia. Dr. W. J. Treanor [18] discussed the restoration of function in patients with spastic hemiplegia. He mentioned that there has been a reawakening of interest in the rehabilitation of these patients but claimed that there is little objective evidence that motor recovery in individual patients has been altered significantly by any form of therapy in the last fifty years. What was described in the early nineteen hundreds as the classical hemiplegic posture is now described by the euphemistic phrase, "a satisfactory rehabilitation result".

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[18] 2200 Hayes Street, San Francisco 17, California.

In a series of 125 patients selected at random, detailed observations had been made as to motor recovery. The patients had been subjected to three different types of regimen. Eleven patients had been observed during the entire cycle of spontaneous (therapeutically-uninfluenced) recovery. Another group of seventeen patients had been treated by the widely-accepted method of early ambulation and training in self-care activities. In the remaining ninety-seven patients, more rigorous attempts had been made to curtail the afferent stimuli which reinforce the already overactive postural muscles. In this group ambulation had been restricted, carefully selected re-education exercises had been prescribed, and self-care activities had been forbidden until late in the recovery cycle.

Early in the treatment of the first group consideration had been given to the possibility that recovery might be aided by the performance of an operation to block temporarily the conduction of the nerves supplying the overactive muscles. Preliminary conduction-block operations had been performed with a local anaesthetic in order to determine what benefits might follow this surgical interruption. Three methods of mechanical blocking had been used: (1) mechanical crushing, (2) supercooling of a small segment, and (3) transection and immediate resuturing.

At the time of writing a total of thirty-five operations had been performed upon twenty-one patients. The three principal sites of the nerve blocks had been the tibial branches to the posterior calf muscles, the femoral branches to the vastus lateralis, and the median branches to the finger flexors.

In terms of improvement in function and cosmetic appearance, the results have been judged satisfactory in thirteen patients. In six patients there had been no improvement, and in two patients the condition had been made worse by the procedure. Satisfactory evidence of the reversibility of the block had been seen in all but six of the patients.

Neurogenic Arthritis and the Problem of Arthrodesis of the Neurogenic Knee. Dr. L. Ward Wiseman [19] had found that despite the decrease in syphilis, neurogenic arthritis is still sufficiently common to be of interest to orthopaedic surgeons. This lesion will occur in association with any disease which interrupts the protective proprioceptive reflex arc at some point along the periphery of the spinal cord. The lesion is still found most often in association with tabes dorsalis but is also frequently associated with pernicious anaemia, diabetes, and syringomyelia. It has perhaps best been described as a fulminating osteoarthritis which occurs following the application of trauma to an ataxic joint.

Arthrodesis is considered the treatment of choice for patients with neurogenic arthritis. It is difficult to obtain a successful result in these patients, however, the reasons for this difficulty including (1) the tendency of the disease to occur in other joints following surgery, (2) the aberrant and abnormal physiology which is associated with the underlying neurological disorder, (3) the presence of sclerotic inactive bone which is susceptible to infection, and (4) the prolonged postoperative immobilization and rehabilitation which is necessary.

Dr. Wiseman reported a series of eighteen patients upon whom twenty arthrodeses had been performed for neurogenic arthritis of the knee. In fourteen of the knees, the arthrodesis had resulted in a successful fusion.

Compression arthrodesis had been found to be the most widely used procedure in the treatment of this disease. When this arthrodesis is properly conducted and supplemented, it results in fusion within a reasonable time in a high percentage of cases.

PRESIDENTIAL ADDRESS

Dr. J. Warren White [20] discussed briefly the origin, migration, and establishment of the Hawaiian branch of the Polynesian race. He called attention to the virtual isolation of this healthy, prolific community for a period of over a thousand years, and he described the advances that the Polynesians are making in their civilization.

Between the early Christian era (600 A.D.), when the Polynesians had first settled in Hawaii, and the year 1778, when Captain Cook of the Royal Navy had discovered the islands on his tragic third voyage of discovery, the Hawaiian population had grown from a few hundred to 300,000. The effect of the Polynesians' first contact with Europeans was deplorable; during the first hundred years, they were nearly decimated, the chief causes of the disastrous death toll having been measles, smallpox, and cholera. Scientific examination of the many remains has revealed no evidence that tuberculosis or syphilis existed at that time. Studies are now being made to explain the early deaths (at thirty-five years of age) which occur in the otherwise healthy Polynesian community.

The remarkable physique of these early Hawaiians, as noted by Cook and subsequent early writers, was discussed, and many instances of their physical prowess and engineering ability were cited.

[19] Los Angeles County General Hospital, Los Angeles, California.
[20] 1020 Kapiolani Street, Honolulu 14, Hawaii.

Wednesday, November 9, 1955

Symposium on Hip Endoprostheses

DR. MURRAY E. GIBBENS [21] reported his experience with eleven patients in whom the hip endoprosthesis had been employed. In ten of these patients, an Austin Moore prosthesis had been used, and in one the F. R. Thompson type had been used. The Gibson posterolateral approach had been employed in all cases, and postoperative bed rest had been continued for three weeks. The ages of the patients had varied from twenty-six to eighty-one years. In ten cases the results were considered successful, and in one the result was considered a failure. Dr. Gibbens emphasized that his series was small and that his experience was limited; he nevertheless claimed that the results obtained to date were gratifying.

Review of Forty-Five Patients with Austin-Moore Endoprosthesis of Hip. DR. MILTON GREENGARD [22], DR. T. W. PENN [23], and DR. JAMES YEE [24] had reviewed a series of forty-five patients in whom forty-six Austin Moore prostheses had been inserted. The operations had been performed at the Oakland Veterans Administration Hospital by five different surgeons. The first operation had been performed in 1952, and the last had been done early in 1955.

The pathological conditions in the forty-five patients operated upon included osteo-arthritis, aseptic necrosis, traumatic arthritis, rheumatoid arthritis, non-union following a fracture of the femoral neck, fresh fracture of the femoral neck, old septic arthritis, and osteochondritis dissecans. The patients had ranged in age from twenty to eighty years, the majority having been between thirty and sixty.

The main indications for surgery, in order of frequency, were loss of motion and shortening of the extremities. The factors influencing the results as regards the general condition of the patient were severe arthritic changes in the spine, bilateral hip involvement, cardiac disease, diabetes associated with blindness, the effects of alcoholism, and pulmonary tuberculosis. Muscle weakness and atrophy were present in all of the patients.

A variety of approaches to the joint had been used, but those most often used had been the posterolateral exposure of Gibson, the lateral incision of Watson-Jones, and the Smith-Petersen approach. In some patients the trochanter had been osteotomized, in others the tendons had been resected, and in two patients adductor tenotomies had been performed at the time of surgery.

The chief method of immediate postoperative care was suspension of the joint by means of a Thomas splint. A few patients had been placed in traction, however, and a very few others had worn the Wilkie boot. Within three weeks after the operation, most of the patients were walking with crutches and were doing assistive and resistive exercises.

The following complications occurred: embolism resulting in death, one case; the formation of a hematoma in the wound, one case; peroneal palsy as a result of suspension, one case; loosening of the screws, three cases; avulsion of the trochanter, four cases; and dislocation of the hip, one case. There had been no instances of infection. Prior treatment had ranged from none at all to a good deal and had included the following: the performance of neurectomies (both anterior and posterior), capsulotomies, subtrochanteric osteotomies, and cup arthroplasties; the insertion of a Judet prosthesis; and the use of various hip nails.

The results were evaluated on the basis of the amount of postoperative pain that was present, the ability of the patient to walk with or without such support as a cane or a crutch, and the ability of the patient to be gainfully employed. According to these criteria the results were excellent in thirteen cases, good in seventeen cases, fair in eight cases, and poor in six cases. In two cases, it was too early to evaluate the results.

The authors concluded that these results were superior to those obtained by any other procedures used in similar cases. They felt that it was too early to give any final opinion on this procedure but said that the early results appeared to be very favorable.

Prosthetic Replacement of the Head of the Femur. DR. EDWARD L. COMPERE [25] reported that the most frequent indications for the replacement of the head of the femur with a metal or plastic prosthesis are (1) the loss of the head or of the head and neck of the femur as a result of infection, and (2) the presence of aseptic necrosis and degeneration within the head. When both hips in a patient are severely damaged, the best results will be obtained by arthrodesis of the most involved hip and arthroplasty (either by Vitallium cup or prosthesis) of the other hip. Arthrodesis of the hip should not be carried out, however, if arthritis of the lower lumbar portion of the spine is present or if the knee on the same side of the body is stiff. When the adductor muscles are shortened or when spasm is present, obturator neurectomies should be done either before the performance of the arthroplasty or at the same operation.

The end results in a few cases were demonstrated.

[21] 1055 Clermont Street, Denver 20, Colorado.
[22] 239 26th Street, Richmond, California.
[23] 8352 Yates Avenue, Chicago 17, Illinois.
[24] 206 Anza Street, San Francisco, California.
[25] 720 N. Michigan Avenue, Chicago 11, Illinois.

Débridement and Panarthrodesis for Spinal Tuberculosis. Dr. R. H. Hall[26] and Dr. B. M. Adamson[27] described a method of treatment for tuberculous spondylitis. This method consists mainly in direct surgical débridement and in combined fusions of the anterior interbody and the posterior vertebral arch. Seven adult patients had been treated in this manner between 1953 and the time of writing.

According to the authors' criteria, the successful arrest of the tuberculous process should include successful surgical excision of the diseased tissue, the attainment of solid fusion of the involved area, and the completion of at least one year of chemotherapy after the operation. Laboratory and clinical evidence of quiescence of the disease should be obtained. The best although not necessarily the most rapid results are assured by the use of preliminary bed rest and chemotherapy. During the preoperative phase large abscesses and sequestra should be removed and pulmonary and other foci should be arrested by the best means available, including resectional surgery. When the disease appears to be quiescent, the first operation may be done. In this operation, the affected area of the spine is excised through either a retroperitoneal "sympathectomy" or a transthoracic approach, the choice of approach depending upon the level of the lesion; the raw bone cavity is then filled with milled bone-grafting material. About two months after the performance of the débridement, a posterior element arthrodesis of the diseased vertebrae is done. At quarterly intervals following this fusion, two-plane bending roentgenograms are made in order that the solidarity of the area may be determined.

In the authors' series there had been only one complication. This complication had occurred because of a technical error: in an attempt to gain a wide exposure, the twelfth thoracic nerve had been sectioned, and as a result a residual weakness had developed in the abdominal wall.

The patients in the authors' series had been followed for a period of one to three years; during this time no evidence of recurrence or of activity of the disease was noted. Although all the areas of fusion had appeared to be solid after about a year, as shown by the two-plane bending roentgenograms, not all the grafts had appeared to have been completely incorporated. Apparently in some cases this process takes two years or more. The six patients who had been operated upon over a year previously had left the hospital and had resumed their previous activities. At the time of writing none of these patients were wearing braces or were restricted in their activity. By the authors' standards, the disease had been arrested in these six cases. The seventh patient had been operated upon in March 1955, and up to the time of writing his progress had been satisfactory.

Dr. John L. Lowrey's[28] discussion of this paper was read by Dr. Samuel Mathews[29]. In five cases, Dr. Lowrey had used an operation that was similar in technique to the authors' procedure. In this operation the vertebral bodies had been debrided and an iliac graft had then been inserted to fill the resulting defect. The results in every case had been successful. In one case there had been an abscess which was 400 cubic centimeters in size, and the entire operation had been performed through the cavity of this abscess; the period of healing following this operation had been uneventful.

The Doctor and the Automobile Accident. Dr. Murray E. Gibbens[21] had recently examined the files of the Colorado State Highway Patrol. As a result of this examination he had concluded that there is no make of automobile in which the rider is "safe" if there is a collision or if the car rolls over. The badly damaged cars reported in the Colorado files had been exactly the same in construction as are those in which most people ride. He had made one encouraging observation in his study of the files, however,—namely, that often, even when the engine compartment of a car had been damaged and the doors opened and bent, the passenger compartment itself had remained intact and had not been badly damaged. He felt that if the riders in these cars had been strapped to their seats, they would not have been thrown out through the open doors and they might have been "safe".

Because of the frequency with which automobile accidents occur and because of the severity of the injuries which result from these accidents, orthopaedic surgeons as well as the general public should be interested in the securing of safer driving. For this purpose Dr. Gibbens recommended the use of such safety devices as seat belts, crash pads, and safety door latches.

In his discussion, Dr. William F. Stanek[30] stressed the importance of Dr. Gibbens' paper and emphasized that doctors should take the initiative in the use of the safety belt, a device which should contribute greatly to the saving of lives. Dr. Stanek said that whiplash injuries of the cervical portion of the spine are frequently associated with a psychological factor and that this factor is often accentuated by the doctor in caring for the patient. No safety belt now in use will prevent the occurrence of whiplash injuries.

Fractures of the Floor of the Acetabulum. Dr. Alfred M. Okelberry[31] reported that, in his

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[27] 5355 Anaheim Road, Long Beach, California.
[28] Honolulu, Hawaii.
[29] 8820 Wilshire Boulevard, Beverly Hills, California.
[30] 1745 Race Street, Denver 6, Colorado.
[31] 115 East South Temple, Salt Lake City, Utah.

experience, fractures of the floor or of the medial wall of the acetabulum (central fracture-dislocations of the hip joint) are most often caused by automobile accidents. In such accidents the head of the femur is driven inward, carrying with it the entire floor of the acetabulum as well as a varying amount of the adjacent bone.

In the treatment of this fracture it is usually not difficult to pull the head of the femur outward and to replace it in its normal position with relation to the remaining weight-bearing articular surface of the acetabulum. The floor fragment may seldom be moved back into its original position, however, and attempts to do this by previous methods have not been successful, resulting in most cases in the development of traumatic arthritis. As with other fractures involving joints, in the treatment of these fractures accurate reduction must be achieved.

Dr. Okelberry had carried out open reduction through an anterior iliofemoral incision in seven patients. The fracture had been approached by subperiosteal dissection and by retraction of the iliopsoas muscle. After this procedure, strong lateral traction had been applied to the fracture fragment. Fixation had been obtained by the insertion of one screw, this screw being placed obliquely backward and medially just beneath the brim of the pelvis a short distance above the acetabulum. The tip of this screw had held the acetabular-floor fragment in place. (In comminuted fractures more than one screw might be required.) Following the operation traction had been continued for one month.

Four of the seven patients on whom this operation had been done were doing well at the time of writing. In the three other patients complete reduction had not been obtained, and traumatic arthritis had developed. The period of follow-up in these cases had varied from six months to four years.

In his discussion Dr. Vernon P. Thompson [32] emphasized the need for wider usage of the open-reduction method in the treatment of fractures of the acetabular floor. He also emphasized the need for bringing the femoral head back beneath the superior aspect of the acetabulum, a portion of the bone which is usually intact. The cases in which failure is likely to occur following treatment by open reduction are those in which both the floor and roof of the acetabulum are extensively disrupted.

Avulsion of the Ischial Apophysis. Dr. Edgar A. Rogge [33] and Dr. Robert L. Romano [34] pointed out that reports of avulsion of the ischial apophysis are relatively infrequent. The mechanism of this injury appears to be the sudden application of maximum tension on the hamstring muscles with consequent detachment of the apophysis, and the injury is most often sustained during the strenuous motion required by such activities as sports and acrobatic dancing.

The authors described the occurrence of the condition in two boys. One of these boys, aged sixteen, had sustained the injury while playing football and the other, aged fifteen, had sustained it while pole vaulting. Symptoms had been present in the former for three years and in the latter for eight months, and both had complained of pain upon moving or sitting and of tenderness upon application of pressure over the involved ischial tuberosity. Changes had been apparent in the roentgenograms, and cures had been effected by the excision of the bone and cartilage comprising the apophysis.

In preparation for the operation the patient should be placed in a prone position. The incision should be curved and should extend from the posterior border of the greater trochanter to the mid-line of the thigh, the curve paralleling the gluteal crease. This incision will permit reflexion of the glutaeus maximus muscle near its insertion, and at least partial reflection of this muscle is necessary if injury to the posterior femoral cutaneous nerve is to be avoided.

Factors of possible importance in the pathogenesis of the condition were discussed.

Ski Fractures of the Fibula. Dr. Edward G. Ewer [35] described a type of fracture of the fibula which he had encountered frequently in his practice. In 90 per cent of his cases the fracture had occurred as a result of a skiing accident, and for that reason he had arbitrarily named it the "ski fracture".

The ski fracture is an oblique, spiral break. It commences at the angle of the fibular-tibiotalar joint, actually entering the joint, and spirals laterally and obliquely upward. It does not disrupt the tibiofibular ligament.

The author reported that it is impossible to reduce this fracture by the closed method. On the roentgenograms the deformity resulting from the break usually appears minor, and as a result, in the past, the general method of treatment has been simply to apply either an ordinary cast or a walking cast. It was found, however, that 36 per cent of the fractures treated by this method alone during the past fifteen years had resulted in serious disability due to pain, swelling, instability, or limitation of motion at the ankle joint.

In his treatment of ski fractures during the preceding nine years, the author had used the open method of reduction, following this procedure by the insertion of a small screw in order to obtain perfect anatomical position and alignment of the bone fragments. In every case in which this method of treatment had been

[32] 11460 Laurelcrest Road, North Hollywood, California.
[33] 546 Medical-Dental Building, Seattle 1, Washington.
[34] 1608 Federal Avenue, Seattle 2, Washington.
[35] 1624 Franklin Street, Oakland 12, California.

used, healing had occurred within eight weeks, whereas in the cases in which closed reduction and fixation by casts had been used, healing had not occurred until after at least twelve weeks and, in some cases, not until after six months.

A survey had been made of all the cases in which disability had been present six months to a year following treatment by the closed-reduction method. In 18 per cent of these cases loose bodies had been present, these bodies acting as joint mice in the ankle joint. Fibrous union had also been present, and there had occurred a disturbance which had taken the form of widening of the ankle-joint mortise. In the patients treated by open reduction, none of these complications had been found.

The authors concluded that in the treatment of "ski fractures", open reduction is the method of choice for the following reasons: (1) solid union is always obtained, (2) anatomical restoration of the normal joint space is possible, (3) the loose bodies may be removed, (4) the period of disability is shortened, and (5) the procedure is simple and may be performed without hazard to the patient.

Thursday, November 10, 1955

Yaws Lesions of Bone. Dr. John R. Schwartzmann [36] and Dr. Fenwick T. Nichols, Jr.[37], presented material concerning yaws lesions of bone. This material had been collected by the authors while they were working in a native hospital on Saipan Island during 1945 and 1946.

In several children seen at the native hospital, the authors had encountered a type of acute osteitis which did not present the usual clinical symptoms of pyogenic osteomyelitis. No pyogenic organisms had been cultured from any of the tissues of these children, but when the material cultured had been taken from cutaneous ulcers, spirochaeta had been found. In many of the children cutaneous yaws had also been found. A review of the literature had suggested the probability that the inflammation was due to yaws, and as the examinations had been continued, secondary and tertiary yaws had been identified, these lesions corresponding in clinical appearance to the descriptions given in the literature.

The material collected by the authors had been carefully studied in order that the efficiency of the treatment used might be determined and in order that a more accurate description of the pathological bone changes might be formulated. In the cases reported by the authors biopsies of cortical bone had been done before any treatment had been offered, and juxta-articular nodules had been excised for use in microscopic studies. In the treatment of the authors' patients, penicillin had been given when it was available. The heavy metals normally employed in the treatment of syphilis had also been used.

In appearance, as shown by microscopic study, yaws lesions present no specific characteristic features during either the osteitic or tertiary phase of the disease. Dr. Howard Hatcher of the University of Chicago had reviewed the microscopic sections made by the authors but had noted no diagnostic features. The microscopic picture of yaws lesions does not resemble that of lesions due to syphilitic osteitis. The authors showed several representative slides of roentgenograms and microscopic sections.

In the authors' series, penicillin, as used, had failed to either control or arrest the acute osteitis, whereas the heavy metals, mapharsen and bismuth, had been very effective, as had been shown by clinical tests.

In the course of their clinical work on the Island, the authors had encountered typical cases of tuberculosis and coccal osteomyelitis. The appearance of the lesions in these cases, as shown by roentgenograms, had in no way resembled the appearance of yaws lesions of the bone.

In his discussion of this paper, Dr. Charles W. Goff [38] emphasized the prevalence of yaws in many parts of the world. He said that in Haiti he had seen hundreds of cases, and he also said that studies of many unearthed skeletons have shown that the disease has been in existence for a long time. A comparison was made between yaws and three other entities, syphilis, pinta, and bejel; in all of these entities the serological findings are positive.

Malignant Tumors of Bone Induced by Beryllium. Dr. Frank R. Dutra [39] described beryllium as a firm, lightweight, dark-gray metal. At one time this metal had been only a laboratory curiosity. Then, twenty years ago, it had been found that beryllium oxide was fluorescent, and this discovery had led to the development of the fluorescent-lamp industry. Since that time it has been found that in an appreciable number of the persons who work in this industry, inhaling the dust of the metal almost daily, a chronic granulomatous disease of the lungs develops. Most of these persons die within two to three years after the development of the disease.

In Dr. Dutra's experiment, three groups of animals (among them nineteen rabbits) had been exposed to dust containing beryllium oxide for a period of nine to thirteen months. As a result of this exposure, osteogenic sarcoma developed in a number of the animals. One of them, a rabbit which had been exposed for eleven months, had died.

[36] 1616 N. Norton, Tucson, Arizona.
[37] 123 East 51st Street, Savannah, Georgia.
[38] 30 Farmington Avenue, Hartford 5, Connecticut.
[39] Eden Hospital, Castro Valley, California.

In a number of human beings who have been exposed to beryllium dusts, the concentration of metal found in the bone was as great as that observed in some of the experimental animals in which sarcoma developed. It should not be inferred from this fact, however, that in the human being osteogenic sarcoma is caused by beryllium; for this supposition there is no proof.

It has been suggested that beryllium might be useful as a constituent of the alloys which are used in bone surgery. As a result of Dr. Dutra's work, however, it would seem clear that beryllium would not be suitable for this purpose.

Dr. Dutra's experiment has demonstrated that there is now available an easy method by means of which osteogenic sarcoma may be induced for research purposes.

Dr. Floyd H. Jergesen [8], in his discussion, described his own experimental work with beryllium. He had inserted pure metallic beryllium into the bones of immature rabbits. After approximately fifteen months osteogenic sarcoma had developed at the sites of the metal implants. Similar experiments had been done with mature rabbits, cats, and dogs; in these animals not a single tumor developed.

Bone-Tumor Pathology. Dr. Charles P. Baker [10] presented a large series of case studies on bone tumors. Most of the tumors described were of the malignant type, and the presentation included roentgenograms, photomicrographs, and kodachromes of gross specimens.

In his discussion of giant-cell tumors, the author contended that these tumors are benign and said that most neoplasms diagnosed as giant-cell tumors are actually osteogenic sarcoma.

Scapulocostal Syndrome. Dr. Richard B. McGovney [11] described his clinical experience with the scapulocostal syndrome. Over a period of three years he had encountered this syndrome in 150 consecutive patients in his private orthopaedic practice.

The scapulocostal syndrome, first named by Michele in 1950, is a unilateral pain complex which involves the shoulder and scapulocostal region and which sends radiating patterns of pain into the neck and head, the deltoid muscle, the arm and hand, and the chest. There appear to be two types of this syndrome: the atraumatic and the traumatic. The atraumatic type is of insidious onset and occurs in patients between the ages of thirty and sixty. Postural or occupational tensions are involved in its development, but there is no history of injury. The traumatic type has a more acute onset and develops in the younger age group following the occurrence of an injury. In both the atraumatic and traumatic types there are trigger points of acute tenderness about the medial angle of the scapula or at the base of the spinous process.

The etiological explanation postulated by the authors is that the syndrome is caused by a complex of factors, including fascial contraction, nerve irritation, and cord-segmental nerve reflex. All of the spinal nerve trunks in the neck pass through the fascia profunda, a structure which is a part of the deep fascia covering the whole body and which is continuous with all the deeper structures by means of the septa.

In 86 per cent of cases, the trigger points are located about the medial angle of the scapula. The predominance of this location is thought to be the result of three factors: (1) the suspensory mechanism of the scapula, (2) the relation of the fascia to the spinal nerves involved in the pain patterns, and (3) the cord-segmental reflex symptoms referred to previously.

The scapula is a suspended bone which articulates with the two other bones of the shoulder girdle. The deltoid has attachments to all three of the shoulder-girdle bones, but its attachment to the scapula is by far the most extensive. In 76 per cent of cases the deltoid is involved, alone or in combination. The one tissue that binds together and therefore acts on all the other deep structures of the neck (the shoulder girdle, muscles, spinal nerves, vascular bundles, and intermuscular septa) is the fascia profunda.

Of the 150 patients seen by the author, 52 per cent were females and 48 per cent were males. In 63 per cent the right side had been involved and in 37 per cent the left, there being no significant difference between the sexes in this regard. The average age of all the patients had been forty-five years, the average for the females being forty-six and the average for the males being forty-four. Eighty-one per cent had been between thirty and seventy. The duration of symptoms up to the time of the diagnosis had averaged eight months in all the patients and had been one year or less in 87 per cent. In 76 per cent the shoulder had been involved as the symptom area, and in 60 per cent the trigger-point area had been in the region about the medial angle of the scapula.

In 49 per cent of the treatment injections, 2.5 cubic centimeters of 2 per cent intracaine had been given in oil. One injection had been sufficient in 63 per cent of the cases, and one or two injections had been sufficient in 86 per cent. Although the patients in this series had been engaged in forty-four different occupations, the majority of them (69 per cent) had been housewives, ranchers, salesmen, students, and office workers. The final results in the series had been as follows: complete relief in 57 per cent of the cases, moderate relief in 33 per cent, and no relief in 10 per cent. Active and passive physical-therapy modalities had been used in combination.

[10] Samuel Merritt Hospital, Oakland, California.
[11] 2950 State Street, Santa Barbara, California.

In cases in which there is unilateral pain in the neck, shoulder, and upper extremity, a diagnosis of scapulocostal syndrome should be considered. Many previous cases of this pain in which no diagnosis could be made may actually have been cases of this syndrome. The patients in such cases may now be satisfactorily treated, the treatment of choice varying according to the needs of the individual.

In his discussion DR. DON E. KING [42] emphasized the frequency of scapulocostal syndrome. He concurred with the author that this pain complex is a clear-cut syndrome, but conceded, as did the author, that nothing definite is known about either its cause or its pathological anatomy; in fact, it is not even known exactly where the lesion is located or what tissues it involves. Dr. King's experience with the treatment of the lesion by local infiltration at the site of the trigger points of tenderness had been similar to the author's; on the whole satisfactory results had been obtained.

The Role of the Posterior Tibial Muscle in Spastic Paralysis. DR. WILLIAM R. DUNCAN [43] and DR. RAYMOND J. ADAMS [44] presented a neurophysiological explanation of the development of equinus deformity in patients with spastic paralysis. Although the tibialis posterior is not powerful enough to hold the foot in an equinus position by its own intrinsic action, it may in many cases constitute the trigger mechanism by which the plantar thrust of the foot into the equinus deformity is initiated. Substantiating this view is the experimental work of Magnus, which showed that in the decerebrate animal the simple spreading of the footpads evokes a total extensor thrust. By virtue of its extensive insertion in the fore part of the foot, the tibialis posterior is stretched at every step. The activity which results from this stretching overflows to the remainder of the calf muscles through the simple spinal reflex arcs, and in this way the total plantar thrust is released.

As a result of the inhibitory or alienating effect of the stretching of the muscles in the calf, there is a loss of active power in the dorsiflexors, as has been shown by Liddell and Sherrington in their animal experiments and as has been demonstrated electromyographically in human beings. Elimination of the antagonistic stretch reflex allows rehabilitation of the dorsiflexors.

Correction of the equinus deformity as well as of the varus deformity of the fore part of the foot has been observed in a substantial number of cases following simple lengthening of the posterior tibial tendon. The indications for this procedure are (1) the presence of an equinus or varus deformity in the fore part of the foot and (2) the presence of an active stretch reflex or clonus in the tibialis posterior.

DR. ERNEST M. BURGESS [45] concurred with the author concerning the importance of the posterior tibialis in the development of spastic paralysis and stated that he had transplanted this muscle in numerous club feet in which it was the most important deforming force.

Incomplete Differentiation of the Peronaeus Longus Muscle. DR. STEELE F. STEWART [46], while treating patients with club feet, had observed that there are various types of deformities which result from isolated tendinous anomalies. His study of this subject had been based upon the reports of multiple tendon dysplasias which had been presented to the Western Orthopedic Association in 1948.

The recent findings of Dr. Stewart have necessitated a re-evaluation of some of the more common foot conditions, especially pes planus. Four varities of pes planus are now recognized; these varieties are as follows:

1. The normal negroid flat-foot, which is strong and painless and which is of diverse architectural patterns.

2. The normal infant flat-foot, which, without treatment, develops into a normal foot. The architecture of this foot is normal, but its motors are slow in development, especially when the foot is restricted by a shoe. Infant flat-foot is iatrogenic and may become psychosomatic.

3. The structurally defective peronaeus longus flat-foot in which the incompletely differentiated peronaeus longus tendon causes supination of the fore part of the foot. Patients with this deformity can obtain a three-point landing only by eversion of the calcaneus. Peronaeus longus flat-foot is relatively rare.

4. The secondary flat-foot which results from an injury or disease. The peronaeus longus flat-foot can be converted into a normally functioning foot by tendolysis of the peroneal tendon between the cuboid pulley and the base of the first metatarsal. The only postoperative care required in this treatment is early weight-bearing and mild muscle training; neither the application of a cast nor the insertion of a prosthesis is necessary.

[42] 2361 Clay Street, San Francisco, California.
[43] 1607 Medical-Dental Building, Seattle 1, Washington.
[44] 1607 Medical-Dental Building, Seattle 1, Washington.
[45] 1110 Harvard Avenue, Seattle 22, Washington.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

One of the largest and one of the most successful Annual Meetings of The American Academy of Orthopaedic Surgeons was held in Chicago, Illinois, under the Presidency of Dr. Walter P. Blount, January 28 to February 2, 1956.

At the second Executive Session, February 2, 1956, the new President, Dr. William T. Green, Boston, Massachusetts, was inducted into office, and the following officers were elected:

President-Elect: Frederic C. Bost, M.D., San Francisco, California
Vice-President: Atha Thomas, M.D., Denver, Colorado
Treasurer: Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania
Secretary: John R. Norcross, M.D., Chicago, Illinois
Librarian-Historian: Albert C. Schmidt, M.D., Milwaukee, Wisconsin
Executive Committee:
Walter P. Blount, M.D., Milwaukee, Wisconsin
Francis M. McKeever, M.D., Los Angeles, California
Joseph S. Barr, M.D., Boston, Massachusetts
Harold B. Boyd, M.D., Memphis, Tennessee
T. Campbell Thompson, M.D., New York, N. Y.
Junior Members of Executive Committee:
Charles H. Herndon, M.D., Cleveland, Ohio
James E. Bateman, M.D., Toronto, Ontario, Canada

Committee appointments have been made pending confirmation by the Executive Committee at its meeting on April 14.

At the First Executive Session, held on January 29, 1956, the following new members were inducted:

John Pletch Adams, M.D., Washington, D. C.
William H. Ainsworth, M.D., Galveston, Texas
Russell Alsfelder, M.D., Hamilton, Ontario, Canada
J. Thomas Aye, M.D., Sharon, Pennsylvania
Robert Wayne Bailey, M.D., Los Angeles, California
Francis F. Baker, M.D., Plattsburg, New York
Joseph M. Barnhart, M.D., Houston, Texas
Stephen Bastable, M.D., Syracuse, New York
Alfred V. Bateman, M.D., Oceanside, California
George W. Bennett, M.D., Elyria, Ohio
Eugene V. Bigelow, M.D., Denver, Colorado
William Griffin Bland, M.D., Gulfport, Mississippi
Dale Clay Bouton, M.D., Newburgh, New York
Gordon T. Bowen, M.D., Lynwood, California
H. Robert Brashear, Jr., M.D., Chapel Hill, North Carolina
Warner D. Bundens, Jr., M.D., Philadelphia, Pennsylvania
Alfred H. Bungardt, M.D., Tulsa, Oklahoma
F. Ashton Carmines, M.D., Newport News, Virginia
Lee Monroe Cattell, Jr., M.D., Kokomo, Indiana
John Howard Cheffey, M.D., Bethesda, Maryland
Winfred H. Clarke, M.D., Portland, Oregon
Mack L. Clayton, M.D., Denver, Colorado
Robert H. Cofield, M.D., Covington, Kentucky
Arthur C. Connor, M.D., Chicago, Illinois
Joseph W. Copel, M.D., Boston, Massachusetts
Oscar Corn, M.D., Philadelphia, Pennsylvania
Arch Evan Cowle, M.D., Madison, Wisconsin
Howard R. Crawford, M.D., Boston, Massachusetts
Sam J. Davis, M.D., Indianapolis, Indiana
Richard De Young, M.D., Houston, Texas
Robert Frances Dine, M.D., Boston, Massachusetts
James M. Donovan, M.D., Salem, Massachusetts
Joseph A. Dorgan, M.D., Brookline, Massachusetts
Roger John Dugan, M.D., San Bernardino, California
Wyllys A. Dunham, M.D., Schenectady, New York
Ernest Goodall Edwards, Jr., M.D., Savannah, Georgia
Rudy John Ellis, M.D., Louisville, Kentucky
Edward A. Evans, M.D., Salt Lake City, Utah
Don Leroy Eyler, M.D., Nashville, Tennessee

Joseph William Fielding, M.D., Dumont, New Jersey
Richard Harding Fisher, M.D., Roanoke, Virginia
Joseph Louis Fleming, M.D., Detroit, Michigan
Darius Flinchum, M.D., Atlanta, Georgia
William D. Francisco, M.D., Kansas City, Kansas
Sanford T. Freedman, M.D., Lawrence, Massachusetts
George Otto French, M.D., San Luis Obispo, California
George E. Froehlich, M.D., New Rochelle, New York
F. James Funk, Jr., M.D., Atlanta, Georgia
Thomas J. Gamble, M.D., Sherman Oaks, California
John J. Gartland, M.D., Philadelphia, Pennsylvania
Robert K. Gassler, M.D., Waco, Texas
Joseph Gendel, M.D., Topeka, Kansas
John Glasson, M.D., Durham, North Carolina
Lester T. Gootnick, M.D., Rochester, New York
John Ervin Gottsch, M.D., Tampa, Florida
Jacob J. Graham, M.D., New York City
Robert J. Graham, M.D., Moline, Illinois
John P. Greene, M.D., Lewiston, Maine
Milton Greengard, M.D., Richmond, California
Charles F. Gregory, M.D., Indianapolis, Indiana
Robert L. Gunderson, M.D., Denver, Colorado
Paul B. Haggland, M.D., Fairbanks, Alaska
Francis J. Haley, M.D., Buffalo, New York
Edward J. Hanley, Jr., M.D., Canton, Ohio
Marvin B. Hays, M.D., Oklahoma City, Oklahoma
Robert D. Heath, M.D., Philadelphia, Pennsylvania
Cline D. Hensley, Jr., M.D., Wichita, Kansas
Lloyd J. Hill, M.D., E. St. Louis, Illinois
John William Hillman, M.D., Nashville, Tennessee
Mason Hohl, M.D., Beverly Hills, California
James E. Holmblad, M.D., Schenectady, New York
Claude D. Holmes, Jr., M.D., Miami, Florida
Richard J. Hopkins, M.D., Portland, Oregon
Charles D. Houck, M.D., Canton, Ohio
John Robert Huey, M.D., Cedar Rapids, Iowa
Charles G. Hutter, Jr., M.D., Hollywood, California
Henry Myles Johnson, M.D., Albuquerque, New Mexico
L. Wayne Johnson, M.D., St. Petersburg, Florida
Kenneth L. Jordan, M.D., Montclair, New Jersey
Louis Kagen, M.D., Milwaukee, Wisconsin
Paul J. Kaminski, M.D., Danville, Illinois
Reid L. Keenan, M.D., Indianapolis, Indiana
Richard Ewart King, M.D., Atlanta, Georgia
Arthur A. Kirk, M.D., Portsmouth, Virginia
Lewis Maxwell Kistler, M.D., North Hollywood, California
Theodore A. Klecka, M.D., San Antonio, Texas
Duane Montgomery Kline, Jr., M.D., Cheyenne, Wyoming
Joseph L. Kurtz, M.D., Atlanta, Georgia
C. W. Lambert, M.D., Pasadena, California
Ivar J. Larsen, M.D., Honolulu, Hawaii
Leroy S. Lavine, M.D., New Hyde Park, New York
Richard W. Leong, M.D., Houston, Texas
Richard Q. Lewis, M.D., Lubbock, Texas
Frank Harry Lindeman, Jr., M.D., Tampa, Florida
Francis C. Link, M.D., Springfield, Ohio
Richard M. Logue, M.D., Little Rock, Arkansas
Eugene Loopesko, M.D., Los Angeles, California
Ivan K. Loughlen, M.D., Seattle, Washington
Anibal L. Lugo, M.D., Santurce, Puerto Rico
William Russell MacAusland, Jr., M.D., Boston, Massachusetts
Michael P. Mandarino, M.D., Philadelphia, Pennsylvania

Cline N. Mapes, M.D., San Bernardino, California
Robert W. Maris, M.D., Spokane, Washington
Henry O. Marsh, Jr., M.D., Wichita, Kansas
James A. Mason, M.D., Portland, Oregon
Charles A. Mead, Jr., M.D., Jacksonville, Florida
August W. Meier, M.D., Palo Alto, California
Harold Clay Messenger, Jr., M.D., Dayton, Ohio
Robert W. Meyer, M.D., Palo Alto, California
William B. Mikita, M.D., Steubenville, Ohio
James S. Miles, M.D., Denver, Colorado
Lawrence Samuel Miller, M.D., Morgantown, West Virginia
Eugene R. Mindell, M.D., Buffalo, New York
Irving E. Miner, M.D., Manhasset, New York
Thomas O. Moore, M.D., Houston, Texas
Si F. Moorehead, Jr., M.D., A.P.O., Seattle, Washington
Seymour Morse, M.D., Jacksonville, Florida
Todd M. Mulford, M.D., Long Beach, California
Ian Douglas Murphy, M.D., Santurce, Puerto Rico
Donald H. McCartney, M.D., Indianapolis, Indiana
Spencer C. McCrae, M.D., Salina, Kansas
F. H. McCullough, Jr., M.D., Oceanside, California
Henry Clare McDonald, Jr., M.D., Fort Worth, Texas
D. Keith McElroy, M.D., New York City
David G. McFadden, M.D. Kitchener, Ontario, Canada
James Allan McQuown, M.D., Greenwood, South Carolina
John J. Neibauer, M.D., San Francisco, California
James A. Nicholas, M.D., New York City
Frank A. Pantalone, M.D., Greensburg, Pennsylvania
James H. A. Peck, Jr., M.D., San Diego, California
Robert K. Penman, M.D., Erie, Pennsylvania
Champe C. Pool, M.D., Harrisburg, Pennsylvania
Edwin J. Powell, M.D., Philadelphia, Pennsylvania
Paul J. Preston, M.D., Hayward, California
George Dewey Purvis, Jr., M.D., Jackson, Mississippi
David C. Ramsay, M.D., Ada, Oklahoma
George I. Raybin, M.D., Jacksonville, Florida
Frederic W. Reichardt, M.D., Stevens Point, Wisconsin
John James Reilly, Jr., M.D., Elizabeth, New Jersey
Russell Paul Rizzo, M.D., Lakewood, Ohio
William John Robb, M.D., Cedar Rapids, Iowa
Ervin E. Rodriguez, M.D., Lewistown, Pennsylvania
John F. Rudolph, Jr., M.D., Utica, New York
Chester A. Sattler, M.D., Kenosha, Wisconsin
Robert Shapiro, M.D., Boston, Massachusetts
Robert J. Sidow, M.D., Fairmont, West Virginia
Herbert M. Simonson, M.D., East Orange, New Jersey
Morten Smith-Petersen, M.D., Boston, Massachusetts
Stanley T. Soholt, M.D., Redwood City, California
Ivan MacDonald Spear, M.D., Worcester, Massachusetts
Donald W. Spiers, M.D., North Hollywood, California
Kenath H. Sponsel, M.D., Minneapolis, Minnesota
William Batte Stanton, M.D., Texarkana, Arkansas
William O. Starks, M.D., Muncie, Indiana
Howard H. Steel, M.D., Philadelphia, Pennsylvania
Capt. Harold A. Streit, Bremerton, Washington
Joseph M. Strong, M.D., Elyria, Ohio
Reuben Stutch, M.D., San Mateo, California
Eugene Suzedell, M.D., Quincy, Massachusetts
Arthur Sweet, M.D., Decatur, Illinois
Paul C. Thompson, M.D., Chattanooga, Tennessee
Alvin Turken, M.D., Hawthorne, New York
Isaac L. Van Zandt, M.D., Fort Worth, Texas

Robert Jachens Vitt, M.D., Tulare, California
Eugene A. White, M.D., Montclair, New Jersey
Hugh L. White, M.D., San Francisco, California
Robert S. Wilson, M.D., Clarksburg, West Virginia
John A. Woodcock, M.D., Bangor, Maine
Joe W. Woodward, M.D., Waco, Texas
Thaddeus A. Wozniak, M.D., Chicago, Illinois
Francis G. Zeier, M.D., Rockford, Illinois

Elected to Honorary Membership was:

Prof. P. Erlacher, Vienna, Austria

The President's Address and an illustrated report of the Meeting will be published in the June issue of *The Journal;* summaries of the Scientific Sessions and the Scientific Exhibits will be published in the July issue.

The next Annual Meeting of The American Academy of Orthopaedic Surgeons will be held in Chicago, Illinois, January 26 to 31, 1957.

ORTHOPAEDIC RESEARCH SOCIETY

The Second Annual Meeting of the Orthopaedic Research Society was held in Chicago, Illinois, on Saturday, January 28, 1956.

SESSION I

Chairman: Robert D. Ray, M.D., University of Washington, Seattle, Washington

8:30 A.M.

Isotope Methods in Clinical Studies of Skeletal Metabolism.
Göran C. H. Bauer, University of Lund, Sweden.

Radioactive Tracer Studies on the Fate of Bone Grafts and Migration of Hot Spots.
Jonathan Cohen, M.D., Boston, Massachusetts;
Constantine J. Maletskos, M.D., Boston, Massachusetts;
John H. Marshall, M.D., Boston, Massachusetts;
James B. Williams, M.D., Boston, Massachusetts.

Histochemical Studies of Normal and Hormone Treated Bone Transplants.
James A. Nicholas, M.D., New York, N. Y.;
Edgar Tonna, M.D., New York, N. Y.

Histological Investigation of Bone Grafts in Immunologically Prepared Animals.
William F. Enneking, M.D., Chicago, Illinois.

The Effect of Administration of Parathyroid Extract on the Absorption of Calcium from the Gastrointestinal Tract.
James Dougherty, M.D., Chicago, Illinois.

SESSION II

Chairman: C. Howard Hatcher, M.D., University of Chicago, Chicago, Illinois

10:30 A.M.

Experimental Trauma to the Lower Femoral Epiphysis in Rabbits.
J. Albert Key, M.D. (*deceased*);
Lee T. Ford, M.D., St. Louis, Missouri.

The Localization of Chloride in Hyaline Cartilage by Histochemical Technique.
Thomas D. Brower, M.D., Pittsburgh, Pennsylvania.

Bone Changes in Chronic Circulatory Insufficiency (A Histopathologic Study).
Mary S. Sherman, M.D., New Orleans, Louisiana;
Walter G. Selakovich, M.D., New Orleans, Louisiana.

Formation and Calcification of the Shell-Repair Matrix in a Terrestrial Snail.
William Colin Durning, M.D., Chicago, Illinois.

Xeroradiography—an Aid in the Recording of Roentgen-Images of Bone Specimens.
J. Crawford Campbell, M.D., Albany, New York;
Andre Grisola, M.D., Albany, New York;
Eichero Asia, M.D., Albany, New York.

12:30 P.M.

Executive Session

SESSION III

Chairman: Herbert E. Pedersen, M.D., Detroit, Michigan

2:30 P.M.

Biomechanics of Bone. The Weakening Effect of Holes of Various Sizes.
Charles O. Bechtol, M.D., New Haven, Connecticut;
Henry Lepper, Jr., M.D., New Haven, Connecticut.

Electromyography in the Lower Extremity.
J. R. Close, M.D., Oakland, California;
B. W. Smart, M.D., Oakland, California;
J. A. Blosser, M.D., Oakland, California.

A Study of Disuse Atrophy in Skeletal Muscle in Animals.
Albert B. Ferguson, Jr., M.D., Pittsburgh, Pennsylvania;
R. LaVerne Vaughan, M.D., Pittsburgh, Pennsylvania.

The Effect of Disuse on the Histochemical Characterization of Skeletal Muscle.
Wayne H. Akeson, M.D., Chicago, Illinois;
Lillian Eichelberger, M.D., Chicago, Illinois.

Bipedal Rats and Mice. New Laboratory Animals.
Charles W. Goff, M.D., New Haven, Connecticut.

4:30 P.M.

Executive Session

READ BY TITLE

The Chronology of Circulatory Changes in Poliomyelitis.
Arthur W. Trott, M.D., Boston, Massachusetts;
Mary D. Hellstrom, M.D., Boston, Massachusetts;
William T. Green, M.D., Boston, Massachusetts.

The Effect of Tension Across the Epiphyseal Plate.
William S. Smith, M.D., Columbus, Ohio;
James B. Cunningham, M.D., Columbus, Ohio.

The Effect of Bone Bank Preservation on the Calcifying Mechanism.
Leroy S. Lavine, M.D., Brooklyn, New York;
Martin Burger, M.D., Brooklyn, New York;
Albert Hirschman, M.D., Brooklyn, New York;
Albert E. Sobel, M.D., Brooklyn, New York.

The Spread of Soft Tissue Sarcomas of the Extremities Along Peripheral Nerve Trunks.
John R. Barber, M.D., Windsor, Ontario, Canada;
Mark B. Coventry, M.D., Rochester, Minnesota;
John R. MacDonald, M.D., Rochester, Minnesota.

The Effect of Intramedullary Nailing on the Growth Rate of the Femurs of Immature Dogs.
Frederick L. Behling, M.D., Rochester, Minnesota;
Joseph M. Janes, M.D., Rochester, Minnesota.

Fat Embolism: The Prophylactic Value of a Tourniquet.
Leonard F. Peltier, M.D., Minneapolis, Minnesota.

Analysis of the Different Etiological Forms of Scoliosis.
Aladar Farkas, M.D., New York, N. Y.

Congenital Abnormalities of the Feet.
Lawrence A. Davis, M.D., Louisville, Kentucky;
William S. Hatt, M.D., Louisville, Kentucky.

Utilization of Radioactive Cobalt in Sterilization of Homogenous Bone Transplants.
Paul H. DeVries, M.D., Ann Arbor, Michigan;
Wade O. Brinker, M.D., Ann Arbor, Michigan;
Lloyd Kempe, M.D., Ann Arbor, Michigan.

A Comparative Histologic Study of Bone Transplants.
Donald S. Maxwell, M.D., Ann Arbor, Michigan;
Carl E. Badgley, M.D., Ann Arbor, Michigan.

A Comparative Roentgenologic Study of Cortical Bone Transplants.
Paul Campbell, M.D., Ann Arbor, Michigan;
Carl E. Badgley, M.D., Ann Arbor, Michigan.

The Effect of Aminonitriles on Fracture Callus in Rats.
Ignacio V. Ponseti, M.D., Iowa City, Iowa;
Fernando Aleu, M.D., Iowa City, Iowa.

ORTHOPEDIC GUILD

The Sixteenth Annual Meeting of the Orthopedic Guild was held in New York, N. Y., on December 2 and 3, 1955.

Friday, December 2, 1955

University Hospital

The Present Status of the Medical Treatment of Rheumatoid Arthritis.
Morris Ziff, M.D.

The End-Results of the Treatment of Rheumatoid Spondylitis.
Theodore A. Potter, M.D.

The Indications for Synovectomy or Arthoplasty in the Treatment of Rheumatoid Arthritis.
John Kuhns, M.D.

The Restoration of Active Motion in Reconstruction Operations for Rheumatoid Deformities.
Robert L. Preston, M.D.

Clinical Impressions of Hip Arthoplasty Procedures.
Walter Thompson, M.D.

The Treatment of Arterial Complications of Orthopedic Surgery.
Jere Lord, M.D.

Institute of Physical Medicine and Rehabilitation

Symposium on Rehabilitation
Howard Rusk, M.D.;
Donald Covalt, M.D.;
Edward Lowman, M.D.

The Neurosurgical Relief of Parkinsons and Fixed Dystonic Deformity.
Irving Cooper, M.D.

Saturday, December 3, 1955

Bellevue Hospital

The Present Status of the Treatment of Bone and Joint Tuberculosis.
David M. Bosworth, M.D.

Problems in the Treatment of Congenital Deformities of the Feet.
John McCauley, M.D.

Recurrent Posterior Dislocation of the Shoulder.
David MacIntosh, M.D.

Ligamentous Injuries of the Knee.
Frederick L. Liebolt, M.D.

Present Day Concepts on Diagnosis and Treatment of Cerebral Palsy
George G. Deaver, M.D.

BOSTON ORTHOPEDIC CLUB

On November 21, 1955, Dr. George Garceau addressed the Boston Orthopedic Club on the subject of "Club-Foot Deformity". In his brief but comprehensive historical review, he started with the time of Hippocrates, who had an amazing grasp of the problem of club-foot, and he concluded with modern times. Following this historical review, Dr. Garceau touched on the etiological factors involved in club-foot and then went on to discuss at length the pathology and the treatment, both conservative and operative.

The theory that club-foot is the result of the "position *in utero*" of the foetus is now considered untenable, and in his address Dr. Garceau emphasized the "determination" hypothesis, which was developed in 1891 by German investigators. According to this hypothesis the development of the various structures in the embryo follows a time schedule. At certain times chemical substances formed by the cells (organizers) are released. These substances produce various effects on given tissues (induction), the tissues affected having the ability to react to the substances at the allotted times (competence). Belief in this concept has been strengthened by the recent work of Duraiswami. Dr. Garceau felt that the presence of a mild fever or illness in the mother might upset the system in the embryo at the time when the feet were being "induced"; he admitted, however, that the causal relationship of such an occurrence would be hard to prove.

In his discussion of etiology, Dr. Garceau pointed out that a hereditary factor was present in 20 per cent of the 100 cases studied, and in connection with this point he showed several family trees. Other etiological factors of a more tangible nature which he mentioned were alteration in muscle development, failure of the

muscle fibers to lengthen, low insertion of the anterior tibial tendon, medial insertion of the Achilles tendon, the presence of accessory tendons, the absence of the extensor digitorum longus and brevis, and the presence of agenesis or dysplasia of the peronei.

In his discussion of the pathology of club-foot, Dr. Garceau made the following observations. Except in cases in which there is absence of the toes or congenital fusion, the bones show only slight abnormalities in structure. In alignment, however, they show definite abnormalities, the forepart of the foot being adducted, the navicular and cuboid being displaced, the calcaneus being inverted, and the calcaneocuboid joint being laterally opened. In cases of club-foot, deficiency in the muscle mass is a common observation, and as an illustration of such a deficiency Dr. Garceau showed microscopic sections of degenerative peroneal muscle from a foetus.

Dr. Garceau pointed out that alterations in the contour of the bones may be produced by treatment. As examples of such alterations he mentioned lateral narrowing of the lower tibial epiphysis due to pressure, the occurrence of ridges in the talus, and flattening of the dome of the talus, the latter change sometimes vitiating any attempt to correct the equinus deformity by means of heel-cord lengthening and posterior capsulotomy.

In his discussion of the treatment of club-foot, Dr. Garceau's principle points were as follows: The best solution to the problem of club-foot has not yet been found, as is shown by the 10 per cent recurrence rate of the deformity and as has been mentioned in many of the articles on the subject. A lasting correction will be obtained if treatment is started early and if the muscles are normal. Recurrence and failure will be the results, however, if the treatment is delayed for three or four months, if the parents are uncooperative, if active treatment is discontinued too soon, and if the basic pathological changes are unfavorable, this last condition perhaps being the most important.

Night splints and corrective club-foot shoes should be used and active exercises should be taken. For early treatment the Denis Browne bar is favored. With this bar, which has been used to treat many patients, there is less danger of faulty correction and the final results may be expected within three months. If the deformity recurs, Kite's method of wedging plasters should be used, especially if the patient is around the age of eight or nine months. For older infants or for children a variety of methods may be used. The medial release of Ober is one possible method, and another is the switch operation of Stewart (although in connection with the latter procedure, the author said the Achilles tendon will assume a normal position if the inversion of the calcaneus is corrected). For adduction of the fore part of the foot, metatarsal osteotomy may be done.

The author described one case in which derotation of the tibia was done with good results. He also described the Stoeffel procedure which he uses in cases of persistent adducto-cavus deformity. In this procedure, the branches of the medial and lateral plantar nerves to the abductor hallucis, the flexor hallucis brevis, the flexor digitorum brevis, and the quadratus plantae are cut. The branches of the small nerves are then electrically stimulated, and if the resulting contracture produces a return of the deformity, these branches are also cut.

A stimulating discussion followed.

Reported by Richard M. Kilfoyle, M.D.

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The Annual Meeting of the American Society for Surgery of the Hand was held in Chicago, Illinois, on January 27, 1956. President for the ensuing year is Lot D. Howard, M.D., San Francisco, California. The following officers were elected:

President-Elect: J. Edward Flynn, M.D., Boston, Massachusetts;
Vice-President: Jerome P. Webster, M.D., New York, N. Y.;
Secretary-Treasurer: George S. Phalen, M.D., Cleveland, Ohio;
Historian: Julian M. Bruner, M.D., Des Moines, Iowa;
Chairman Program Committee: Donald R. Pratt, M.D., San Francisco, California.

The following were elected to membership in the Society:

John L. Bell, M.D., Chicago, Illinois
William E. Browne, M.D., Boston, Massachusetts
Bradford Cannon, M.D., Boston, Massachusetts
Herbert Conway, M.D., New York, N. Y.
William F. Flynn, M.D., Boston, Massachusetts
Paul R. Lipscomb, M.D., Rochester, Minnesota
Donald C. Robertson, M.D., Toronto, Ontario, Canada
Lee Ramsay Straub, M.D., New York, N. Y.

The next Annual Meeting of the American Society for Surgery of the Hand will be held in Chicago, Illinois, on January 25, 1957.

JOHN ALBERT KEY
1890–1955

Dr. John Albert Key died at his country home near Steelville in the Ozarks on August 6, 1955. His friends and colleagues mourn his passing. His integrity, human qualities, and kindly criticism, always tempered by an ever-ready wit, will long be remembered. His undeviating honesty and fine understanding of his fellow man and his multiplicity of interests and enthusiasm for the endeavors of others made him a warm and affectionate friend and a charming companion. Always unselfish and devoted to duty, he knit into the fabric of his life the respect, love, and admiration of all who knew him.

Dr. Key attended the Alabama Polytechnic Institute where he earned a Bachelor of Science degree in 1913, following which he entered Johns Hopkins University as a member of the Class of 1917. Because of financial reverses, he had to discontinue his medical training for about a year. Such a misfortune as insufficient funds would have daunted a less hardy soul than Albert Key, but he capitalized on his financial setback. He taught anatomy at the University of Chicago and Creighton Medical School. While supporting himself, he studied assiduously to become even more proficient in anatomy. He was able to return to Johns Hopkins University and to join the Class of 1918. The interlude spent in teaching anatomy may well have led him into the realm of orthopaedic surgery, since that discipline is primarily related to anatomy both gross and functional.

Early in 1917, because of the continuing war in Europe and the expectation that the United States would be forced to take up arms, Dr. John Finney organized a war hospital unit at Johns Hopkins and conceived the idea of allowing medical students to serve in the capacity of interns. Albert Key was one of the thirty-two students who volunteered, and, when the United States entered the war, he enlisted with the others as a private in the Army Medical Corps. The months that followed were filled with new experience and hard work for John Albert and for the others who made up the Johns Hopkins Hospital Unit No. 18. They landed

in St. Nazaire, France, in June of 1917. The Unit was moved to Savenay and then to Bazoilles-sur-Meuse. There it occupied a hospital with barracks built around a central building which was called "the chateau". As "students", Albert and his group were assigned to work as interns when there were patients and they were relegated to the "clean-up squad" when there were none.

During the winter of 1917–1918 he worked on the Unit's orthopaedic ward. During the spring of 1918 the students received cablegrams from their University informing them that they had been awarded their degrees as Doctors of Medicine. Soon after he was transferred, and in the months that followed he worked with a Rehabilitation Battalion which had been organized under the general planning of Dr. Joel E. Goldthwait.

During his service at Bazoilles, Dr. Key courted and married Eleanor Myer, an attractive nurse affiliated with the Unit. Later there were two sons, John Albert, Jr., and Frank. Dr. Key was greatly admired for his rare devotion to his family, and when John Albert, Jr., was reported missing in action while serving as an Air Force pilot in the Pacific Theater in 1943, intimate friends were convinced that Dr. Key would never recover from the shock of the tragedy.

From 1919 to 1922 he received his graduate training at the Children's Hospital and Massachusetts General Hospital in Boston. A portion of this time was spent with Dr. James Stone, Chief of the Surgical Service at the Children's Hospital, under whose excellent guidance Dr. Key received his general surgical training. During the latter part of this time he was Resident in Orthopaedic Surgery at Massachusetts General Hospital on the service of Dr. Robert B. Osgood. Dr. Goldthwait was then at Devereaux House in Marblehead, Massachusetts, and with ambitious energy Albert also followed courses there, meanwhile having garnered a Peabody Scholarship. He utilized part of his time on that scholarship to undertake some hematological investigations. He had been attracted to hematology during his first year in medical school and was particularly interested in the histological study of blood and bone marrow. His endeavors in this field were successful, and he published two important papers: "Studies on Erythrocytes with Especial Reference to Reticulum, Polychromatophilia and Mitochondria" and "Lead Studies. IV. Blood Changes in Lead Poisoning in Rabbits with Especial Reference to the Stippled Cells". Men of authority in the field of hematology speak of these papers as excellent fundamental studies.

In 1921 he became Instructor in Applied Physiology at Harvard University and, in the following year, he went to the University of Maryland as Instructor in Orthopaedic Surgery.

In 1924, it was the aim of the National Advisory Board of the Shriners' Hospitals for Crippled Children to have their institutions throughout the country represent the highest clinical standards. In addition, through laboratory and clinical research, they planned to make contributions to the investigation of the cause, prevention, and treatment of crippling conditions in childhood. Dr. Key was appointed Director of Research for all the Shriners' Hospitals, with headquarters in St. Louis.

From 1924 until the end of 1930 I was, while Chief Surgeon at the St. Louis Unit, fortunate to have had the opportunity to observe his research, to become familiar with his ability as a teacher of undergraduate and postgraduate students, and to be stimulated by his keen interest in the clinical problems of crippled children. He contributed much to our service and took an active part as an operating surgeon, in ward rounds, and in the out-patient service. More than simply a colleague, Albert became my friend, and I venture to say no man ever had a truer one. In discussion, although he always spoke with frankness, vigor, and honesty, his never-failing geniality and good humor left no room for bitterness. Unfailingly his repartee was sparkling, but without a barb; his brilliant logic and even temper, his willingness to allow others to explore the great reaches of his intellect and tremendous mental capacity, gave him his rightful place as counselor, guide, and mentor in matters orthopaedic. He made the words "orthopaedic surgery" and "progress" almost synonymous, and he ranks among those who laid the foundation for orthopaedic surgery as a specialty. Dr. Key had begun fundamental research early in his career and never abandoned this work. He continued his work along these lines and always correlated his research work with the clinical approach.

In spite of his multitudinous duties at the Shriners' Hospital, his enormous ability for work enabled him to make outstanding contributions in experimental and clinical studies. During this period "The Reformation of Synovial Membrane in the Knees of Rabbits After Synovectomy", "The Mechanisms Involved in the Removal of Colloidal and Particulate Carbon from Joint Cavities", and the "Cytology of the Synovial Fluid of Normal Joints" were among his outstanding works.

In 1928, he published some thought-provoking articles on arthritis, among which were "Experimental Arthritis. The Reactions of Joints to Mild Irritants" and "The Pathogenic Properties of Organisms Obtained from Joints in Chronic Arthritis". Experimentally, by creating defects in the articular cartilage in the joints of animals, he produced changes very similar to those seen in chronic hypertrophic arthritis. His results were published under the titles "Experimental Arthritis. The Changes in Joints Produced by Creating Defects in the Articular Cartilage" and "Traumatic Arthritis." He was not unmindful, however, of the clinical aspects of his chosen field and published "The Non-Tuberculous Hip in Early Life. II. Childhood", "The Non-Tuberculous Hip in Early Life. III. Adolescence", and "Some Diagnostic Problems in the Hip in Early Life." About this time Dr. Key wrote an article on brittle bones and blue sclera which he termed "hereditary hypoplasia of the mesenchyme". This article contains the original description of the tissues,

including skin, tendons, blood vessels, muscles, bones, and joints, in a case studied from the clinical, roentgenographic, and laboratory aspects. His artiel "Epiphyseal Coxa Vara", which contains an exhaustive bibliography, was accepted as his thesis for membership in The American Orthopaedic Association. He contributed two sections, one on "Idiopathic Bone Fragility (Osteopsathyrosis)" and the other "Fractures and Dislocations of the Extremities" as part of *Graham's Surgical Diagnosis*.

The integrity of his publications, as of all his work, is and will remain beyond question. Professionally and socially, Albert believed in and lived the truth. With Dr. Sherwood Moore, in 1928, he made an English translation of *Normal and Pathological Physiology of Bone*, from the original French by Leriche and Policard. Since he had but little opportunity, he spoke almost no French; upon reading his impeccable translation, Leriche inquired how he had been able to surmount the difficulties of a foreign language. With his flair for absolute truth, Albert replied, "Avec le dictionnaire".

He became associated with the Washington University School of Medicine in 1926 as Associate in Clinical Orthopaedics; in 1927, he was appointed Assistant Professor of Clinical Orthopaedics and, in 1931, Head of the Division of Orthopaedic Surgery and Clinical Professor. Although his hospital duties were long and arduous, often when they were finished, sometimes as late as five in the afternoon, his terrific drive compelled him to begin work on some project of his own. In such an endeavor, his critical and analytical mind had full scope. He was full of intellectual curiosity. Not only was he diligent and persistent in his investigation, he was original. His original ideas were never-ending, and he pursued not one, but many simultaneously. Once he stated that he had decided long before that one should not select a single research project and pursue it to its conclusion, but that it was better to keep working on other subjects simultaneously. Otherwise, in working to complete but one, a person might be slowed down and thus spend years to finish it.

His own drive was a great stimulus to those with whom he worked. He was constantly trying to advance his younger men and associates into positions at the school and toward membership in orthopaedic societies. Several times he said that he hoped some day his younger men would be among the leaders in orthopaedic surgery. He was totally unselfish both with his time and his money. He made private loans to those who needed them, and it is known that he paid the salary of his first Fellow in Orthopaedic Surgery at Washington University. Furthermore, he became interested in the School of the Ozarks. This was a small Missouri school whose interests were directed mainly toward the education of underprivileged children. Each year Dr. Key endowed a likely scholar with a Fellowship.

Immersed though he was in serious work, his love and zest for sports always managed to shine through. I shall never forget the fishing trips we took together in California, Idaho, Oregon, and British Columbia. There was never a dull moment, due to his unfailing good humor, his ready wit, and his joy in seeing others catch more and bigger fish than he did.

He was always the center of attraction in any gathering, whether in mixed company or professional groups. His ability to start a conversation and to control it was unique. He had as broad a knowledge of orthopaedic surgery and of general medicine as anyone I know. He was extremely kind and modest to the point where, when asked to give a paper or make some other presentation, he willingly shared his honor with one of his colleagues; in fact, he often turned the whole matter to the other man's credit. He was never too busy for a conference on a problem—research, clinical, or otherwise. He had a prodigious memory, especially for the minutiae in orthopaedic literature. His presence at any function, social or medical, was practically a guarantee of its success. He was an active member of Theta Nu Epsilon, Gamma Alpha, Alpha Omega Alpha fraternities, and was a Phi Beta Kappa.

In 1955 he became Professor Emeritus of Clinical Orthopaedics at Washington University in St. Louis and head of the Division of Orthopaedics, a position which he held until his death.

Although his entire life was productive, he made especially valuable contributions to the progress of orthopaedic surgery during the years 1931–1955. Among them was the excellent book *The Management of Fractures, Dislocations, and Sprains* by Key and Conwell. In *Cowdry's Special Cytology* he described synovial membranes, joints, and bursae. He found time to contribute to *The Practitioners Library of Medicine and Surgery, Military Surgical Manual of the National Research Council, Clinics, Instructional Course Lectures of The American Academy of Orthopaedic Surgeons, Lewis' Practice of Surgery, A Textbook of Surgery by American Authors*, Bancroft and Murray's *Surgical Treatment of the Motor-Skeletal System*, Ghormley's *Orthopaedic Surgery, Cirurgia de Urgencia*, Cole's *Operative Technic* and *Clinical Orthopaedics*. Among his many articles which have appeared in scientific journals he will be remembered for his work on osteogenesis, bone atrophy and absorption, the use of the sulfa drugs in clean and infected wounds of both soft parts and bone, experimental and clinical observation of the effects of compression in arthrodesis, lesions of the intervertebral disc in the production of backache, and countless other topics. He was a member of the Committee for Investigation of the Kenny Treatment of Poliomyelitis appointed by The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the Section on Orthopaedic Surgery of the American Medical Association. His constructive criticism of the Kenny method of treatment in infantile paralysis and his evaluation and report on this method of treatment remain a masterpiece.

It has been said that he never missed a meeting of The American Orthopaedic Association, an association

of which he was President during 1945 and 1946. At the meetings of The American Academy of Orthopaedic Surgeons, his contributions to discussion were eagerly sought. His knowledge of orthopaedic surgery was so profound that, in discussing papers, he could seize on the salient points and illuminate them as nobody else could. He was a member of the American Medical Association, American Surgical Association, American College of Surgeons, American Radium Society, Missouri Medical Association, Orthopaedic Research Society (of which he was President at the time of his death), Clinical Orthopaedic Society, Southern Medical Association, Southern Surgical Association, and the Robert Jones Club. The meeting of this Club in St. Louis in 1954 was organized by Dr. Key, and he had the fullest cooperation from his confreres; although he was most grateful, he suffered from "an embarrassment of riches"—everyone wanted to speak on his program. Needless to say, the meeting was a great success. Adding to that success, he invited all the members of the Club for dinner at his home in St. Louis, an evening long to be remembered. Some of us were fortunate enough to spend a week end with him at the "Keyhole", his country place in the Ozarks.

Dr. Key presided at the first Orthopaedic Section of the Forum on Fundamental Surgical Problems of the American College of Surgeons in 1951. He organized this section of the Forum and all succeeding meetings of this section until his death. These meetings were held at the time of those of the Congress of the American College of Surgeons.

His Presidential Address before The American Orthopaedic Association, "Education and Certification of Orthopaedic Surgeons", bears the imprint of his clear and lucid mind. This article contains what I would consider fair and just criticism of the National Board of Orthopaedic Surgery. Dr. Key did not arrive at his conclusions without long and considered judgment. He voiced his objection to the regimentation of orthopaedic surgeons and to a self-perpetuating Board, which existed at that time. In his analysis of the group comprising The American Orthopaedic Association, he found that their qualifications for this specialty varied and that their success had been obtained by a variety of routes. He objected to a uniform, prescribed method of training and, as he stated in the final paragraph of his Address as delivered to the Association, ". . . I suggest that our Board alter radically their policy of demanding that a candidate follow a rigidly outlined course of orthopaedic training and that they recognize the incontrovertible fact that satisfactory orthopaedic surgeons have been and can be developed in many different ways. Their standards of excellence should not be lowered and they can demand more time devoted to practice, but they should not close the door of our specialty in the face of men who are well qualified, but whose education has not been along the lines which they have laid down. They are not omniscient but with the best of intentions they are becoming omnipotent and this is not to the best interests of orthopaedic surgery of the future. Finally it is to be reiterated that the function of the Board is to establish minimum standards for the practice of and not to dictate the future development of orthopaedic surgery." This Presidential Address should be read and re-read by all aspirants to the field of orthopaedic surgery, as well as by those who have already arrived, for stripped of all unnecessary verbiage as it is, it contains the outline of basic training, educational requirements, and necessary qualifications for a true orthopaedic surgeon.

Dr. Key loomed large on the medical horizon, and honors were heaped upon him. During World War II he served as Consultant in Orthopaedic Surgery to the Secretary of War and received the Selective Service Medal from the Congress of the United States for loyal and faithful adherence to duty given voluntarily and without compensation.

"The Key era is over . . .", for there will never be another man to take the place of John Albert Key. His loss is irreparable. He was a man who offered his mind, his heart, his earthly possessions, and his friendship generously. His friends are legion, for he was a rare spirit whose belief in his fellow man remained untarnished throughout his long, useful, and productive life. He loved the truth and lived it. Having attained the highest honors in his chosen profession, he did not look down from that height, but rather held out both his hands to those below in a sincere and grateful effort to share with them in recognition for all he believed they had done to help him. And in some measure, he has shared with all, for each man is better for having known him.

On the pages that follow is given a list of his contributions to the literature of orthopaedic surgery. It has been an inspiration to me to review a large part of them and to realize how much had been accomplished by this one man who was dedicated so whole-heartedly to his work. These articles should be required reading for every young man in training to be an orthopaedic surgeon.

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ALBIN LAMBOTTE

1866–1955

The life of Albin Lambotte will be, one can hope, the subject of a book-length biography. It is a record to place him in the front rank of orthopaedic surgeons of all time and also among the great personalities of medical history.

He was doctor, surgeon, pioneer in the surgical treatment of fractures and in osteosynthesis; inventor and designer of instruments and appliances which are easily recognizable as the patterns for equipment that will be made ready for some distinguished surgeon today; master-mechanic, who turned out in his own workshop the instruments he needed for his pioneer work in the operating-room; musician and artist, who could relax by sketching or by playing Bach on one of the violins he had himself made; generous and beloved teacher; fighter, who persisted against long and strong professional opposition to win, finally, a host of world-spread honors and who died in comparative poverty at the age of ninety in Antwerp, on August 1, 1955.

Albin Lambotte was graduated from the University of Brussels in 1891 and went directly as an intern to the Stuyvenberg Hospital in Antwerp. His professional baptism came that same year when cholera ravaged the city. Volunteering, Lambotte performed enterostomies followed by intestinal washing. Two years later diphtheria decimated the city. There was no serum. By seventy-two tracheotomies Lambotte saved sixty lives. He was placed in charge of the small-pox ward.

In 1894 Lambotte performed, successfully, his first gastrectomy.

In 1900 he succeeded Dr. León Desguin as Chief Surgeon of the Stuyvenberg Hospital and performed his first laminectomies and craniotomies. He advocated, fifty years ago, in carefully selected cases of cerebral hemorrhage, prompt trephining and removal of the blood clot. Thirty years ago he insisted that the only justifiable method of treating osteoarticular tuberculosis was immediate and complete cleaning out of the focus of infection even though it involved extensive bone resection. This was before the days of antibiotics. His colleagues shrugged their shoulders.

Although his reputation as a general surgeon had already spread beyond the borders of Belgium, it

was in a professional atmosphere of indifference and even hostility that, in 1902, he began his work on osteosynthesis of the femur. He faced at once the absence of tools for his new trade. In the following years, his time was divided between operating room and his workshop where he designed, forged, hammered and, on his lathe, turned his devices for fixation and the instruments for manipulating them. As he made them, he tried them. If they performed acceptably, he made a model and sent it to Paris, to Collin, who had an un-

Dr. Lambotte's workshop. (Reprinted by permission from *Acta Orthopaedica Belgica*, **21**: 391, 1955.)

The lathe which Dr. Lambotte used for more than fifty years. (Reprinted by permission from *Acta Orthopaedica Belgica*, **21**: 392, 1955.)

Dr. Lambotte after operating in Buenos Aires, Argentina. From left to right are: Prof. José Valls, Dr. Lambotte, Prof. Finochietto, and Prof. Verbrugge. (Reprinted by permission from *Acta Orthopaedica Belgica*, **21**: 397, 1955.)

bounded admiration for his work. Lambotte believed that tool-making was excellent training for the techniques of orthopaedic surgery. He impressed the value of this form of manual training on all his students. They learned to drill with precision, to saw a straight line, to tap a thread smoothly. His relationship to them was alternately that of professor to students and that of master-workman to apprentices. His book, never translated, "Chirurgie Operatoire des Fractures" was published in Paris in 1913.

The many testimonials that have appeared since his death are all eloquent of Albin Lambotte's influence on his students and their affection for him. His interests covered many fields in addition to surgery and all were included in his teaching. He loved music, loved to make music. He was quite happy as one of a chamber-music quartette. He became a violin maker, designed a new bridge, made violas, violins, and violin cellos. The Queen of Belgium, the conservatories of Paris, Brussels and Antwerp are proud possessors of his handiwork. He read widely and catholically, from Plutarch to Perrault to Simenon. His interest in art made him first a frequenter of museums and then, typically, a sketcher of no mean talent and an accomplished wood-carver.

In the interests of surgery, he travelled widely. On a long voyage to Buenos Aires he became interested in astronomy and, once back in his workshop, made a telescope. An ardent fly fisherman, he designed and made his own featherweight reel and his own split-bamboo rod. All of these interests he offered to the men who studied under him.

He roused, the day before his death, to say to his wife: "The greatest crime a man commits against himself and humanity is to be inactive".

In preparing this tribute to Albin Lambotte *The Journal* is deeply indebted to Dr. Robert Soeur, Brussels, President of the *Société Belge d'Orthopédie*, to Dr. Jean Verbrugge, Antwerp, Corresponding Editor of *The Journal*, to Dr. Walter Dauw, Antwerp, for some years assistant to Dr. Lambotte, and to Dr. Irwin S. Leinbach, St. Petersburg, Florida.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-Ninth Annual Meeting of The American Orthopaedic Association will be held at Banff, Alberta, Canada, June 20 to June 23, 1956, under the presidency of Dr. Paul C. Colonna. The tentative program of the Meeting as submitted by the Program Committee is as follows:

Wednesday, June 20

9:00 A.M.

Cervical Spine Fractures and Dislocations Treated with Dependent Head Traction.
Hira E. Branch, M.D., Flint, Michigan (by invitation).

Further Evaluation of the Use of Intermedullary Nailing in Treatment of Gunshot Fractures of the Extremities.
Col. Ernest A. Brav, Washington, D. C.

An Evaluation of the Surgical Use of Metals in Children.
Jean Verbrugge, M.D., Antwerp, Belgium (by invitation).

Bio-Mechanical Problems of Placing Metal Screws in Bone.
Charles O. Bechtol, M.D., New Haven, Connecticut.

Executive Session.

Thursday, June 21

9:00 A.M.

A Long-Term End-Result Study of Spinal Fusion in Children.
Halford Hallock, M.D., New York, N. Y.

Vertebral Growth and Spine Fusion.
Joseph C. Risser, M.D., Pasadena, California.

Surgical Approaches to Vertebral Bodies in the Cervical and Lumbar Regions.
Wayne O. Southwick, M.D., Baltimore, Maryland (by invitation).
Robert A. Robinson, M.D., Baltimore, Maryland.

Osteogenic Sarcoma.
Mark B. Coventry, M.D., Rochester, Minnesota.

Treatment of Volkmann's Contracture by Excision of Infarct.
H. J. Seddon, F.R.C.S., London, England.

Friday, June 22

9:00 A.M.

Arthrographic Studies of the Shoulder Joint.
Graham A. Kernwein, M.D., Rockford, Illinois.

Problems of Soft-Tissue Calcification as Related to the Orthopaedic Surgeon.
H. Relton McCarroll, M.D., St. Louis, Missouri.

A Study on Bone Replacement.
Robert D. Ray, M.D., Seattle, Washington.

The Function of Bone in Calcium and Phosphorus Regulation.
D. Harold Copp, M.D., Vancouver, British Columbia, Canada (by invitation).

11:00 A.M.

Questions from the Floor.

11:10 A.M.

Presidential Address.
Paul C. Colonna, M.D., Philadelphia, Pennsylvania.

Saturday, June 23

9:00 A.M.

The Treatment of Slipped Femoral Epiphysis by Gentle Manipulation and Bilateral Leg Casts.
J. Hiram Kite, M.D., Atlanta, Georgia.

Slipped Femoral Epiphysis with Severe Displacement. A Conservative Operative Treatment.
Clarence H. Heyman, M.D., Cleveland, Ohio.

Prosthetic Replacement of the Femoral Head.
Frank E. Stinchfield, M.D., New York, N. Y.
Indication for and Results of Mold Arthroplasty.
Otto E. Aufranc, M.D., Boston, Massachusetts.

11:10 A.M.
Second Executive Session.

LILLY ENDOWMENT AWARD

The American Orthopaedic Association announces with pleasure and sincere gratitude an award in the amount of $5,000.00 from the **Lilly Endowment, Inc.,** Indianapolis, Indiana, to the **Exchange Fellowship Fund of the Association.** One-half of this sum has been received to be applied toward the tour for the Visiting Fellows from Great Britain this spring; the remainder will be used in 1957 for the joint American-Canadian group visit to Great Britain.

We express here our deep appreciation to Lilly Endowment, Inc., and to Mr. and Mrs. J. K. Lilly, of Indianapolis, in particular, for their help and interest in this worth-while program.

AMERICAN BOARD OF ORTHOPAEDIC SURGERY

Final date for filing applications for the Part II Examinations to be given in January 1957, in Chicago, is August 15, 1956. Application should be made to the Secretary, Dr. Sam W. Banks, 116 South Michigan Avenue, Chicago 3, Illinois.

GORDON RESEARCH CONFERENCES
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The Gordon Research Conferences of the American Association for the Advancement of Science for 1956 will be held from June 11 to August 31 at Colby Junior College, New London, New Hampshire, New Hampton School, New Hampton, New Hampshire, and Kimball Union Academy, Meriden, New Hampshire.

The Conferences were established to stimulate research in universities, research foundations, and industrial laboratories. This purpose is achieved by an informal type of meeting consisting of scheduled lectures and free discussion groups. Sufficient time is available to stimulate informal discussions among the members of a Conference. Meetings are held in the morning and in the evening, Monday through Friday, with the exception of Friday evening. The afternoons are available for recreation, reading, or participation in discussion groups as the individual desires. This type of meeting is a valuable means of disseminating information and ideas which otherwise would not be realized through the normal channels of publication and scientific meetings. In addition, scientists in related fields become acquainted and valuable associations are formed which result in collaboration and cooperative effort between different laboratories.

It is hoped that each Conference will extend the frontiers of science by fostering a free and informal exchange of ideas between persons actively interested in the subjects under discussion. The purpose of the program is not to review the known fields of chemistry, but primarily to bring experts up-to-date as to the latest developments, analyze the significance of these developments, and to provoke suggestions as to underlying theories and profitable methods of approach for making new progress. In order to protect individual rights and to promote discussion, it is an established rule of each Conference that all information presented is not to be used without specific authorization of the individual making the contribution, whether in formal presentation or in discussion. No publications are prepared as emanating from the Conferences.

The first meeting of each Conference is held Monday morning at 9:00 A.M., Eastern Daylight Saving Time. The morning sessions, through Friday, are scheduled from 9:00 A.M. to 12:00 Noon. The second session of each day is held in the evening from 7:30 to 10:00 P.M., Monday through Thursday. There are no Friday evening meetings. Conference members are expected to release their rooms not later than Sunday morning unless they have made a reservation for the next Conference.

Accommodations are available for a limited number of women who wish to attend each Conference, as well as for wives who wish to accompany their husbands. All such requests should be made at the time of the request for attendance because these limited accommodations will be assigned in the order that specific requests are received. Children twelve years of age and older can be accommodated. Dogs or other animals will not be permitted in the dormitories.

Individuals interested in attending the Conference are requested to send in their applications to the Director. Each applicant must state the institution or company with which he is connected and the type of work in which he is most interested. Attendance at each Conference is limited to 100.

Requests for attendance at the Conference, or for any additional information should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island. From June 11 to August 31, 1956, mail should be addressed to Colby Junior College, New London, New Hampshire.

GORDON RESEARCH CONFERENCE

CHEMISTRY, PHYSIOLOGY, AND STRUCTURE OF BONES AND TEETH
R. F. Sognnaes, *Chairman*, D. H. Copp, *Vice-Chairman*
JULY 16 TO 20
Kimball Union Academy, Meriden, New Hampshire

16 July:

G. Wislocki, *Chairman*. Ground Substance.
K. Meyer: Chemical Nature of Ground Substance.
L. Belanger: Histochemical Distribution of Ground Substance in Bones and Teeth.
D. W. Fawcett, *Chairman*.
S. Glasstone-Hughes: Experimental Studies in Tooth Development.

17 July:

W. Neuman, *Chairman*. The Skeleton as an Alkaline Reserve.
W. Stoll: Chemical Studies on the Nature of Bone Sodium.
G. B. Forbes: The Contribution of the Skeleton in Sodium Homeostasis.
R. Bogoroch, P. Yen, J. H. Shaw, and R. F. Sognnaes: Comparative Studies of Radiosodium Turnover in Bones and Teeth of Rats and Rhesus Monkeys.
W. D. Armstrong, *Chairman*.
Y. Eriesson: Solubility of Calcium Phosphate with Special Reference to the Liquid-Solid System of Saliva, Enamel, and Tartar Deposition.

18 July:

M. Logan, *Chairman*. Citric Acid and Vitamin D.
L. Singer and W. D. Armstrong: *In Vitro* Studies on Uptake and Turnover of Citrate in Calcified Tissues.
M. S. Thompson and A. B. Hastings: Factors Affecting the Citrate Content of Hydroxylapatite.
J. Crawford, D. Gribetz, W. Canada, P. Hurst, and B. Castelman: Influence of Vitamin D on Calcium and Citrate Metabolism in Rats.
P. E. Boyle, *Chairman*.
J. T. Irving: A Comparison of the Influences of Various Dietary Factors upon the Calcification Sequences in Enamel, Dentin, and Bone.

19 July:

R. Harris, *Chairman*. Bone Seekers.
J. C. Aub and W. B. Looney: Long-Term Observations Following Administration of Radium, Lead, and Thorium.
J. Jowsey: Mechanism of Yttrium, Strontium, and Sulphur Deposition in Bone.
H. Foreman: Mode of Plutonium and Strontium Combination with Bone.
F. C. McLean, *Chairman*.
B. Engfeldt: Bone and Tooth Pathology Investigated by Microradiography and Microinterferometry.

20 July:

H. Hodge, *Chairman*. Panel Discussion on the Mechanism of Calcification.
R. S. Bear: Structure of Collagen.
W. F. Neuman: The Earliest Events in Calcification.
R. A. Robinson: Crystal-Water Replacement During the Calcification of Osteoid.
A. E. Sobel: The Initiation of Calcification.

THE AMERICAN BOARD FOR CERTIFICATION OF THE PROSTHETIC AND ORTHOPEDIC APPLIANCE INDUSTRY, INC.

At the Annual Meeting of the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc. held in New Orleans October 16–19, the election was announced of Dr. Robert Mazet, Jr., of Los Angeles as President for the year 1955–56. Dr. Mazet, who has served on the Board since 1954, by nomination of the Academy, is the first orthopaedic surgeon to be elected President of the Board. He served as Vice-President during the preceding year.

Other events of interest to orthopaedic surgeons included:

1. The election of Dr. Roy M. Hoover of Roanoke, Virginia, to the Certification Board for a three-year term. Dr. Hoover's name was submitted by the Executive Committee of The American Academy of Orthopaedic Surgeons. Also elected to serve on the Board with Dr. Hoover were McCarthy Hanger, Jr., of St. Louis, Missouri, former President of the Orthopedic Appliance and Limb Manufacturers Association; and Edward W. Snygg of San Francisco, a certified prosthetist and orthotist.

2. The annual examinations for prosthetists and orthotists: a record class of twenty prosthetists and thirty-three orthotists took the two-day series of tests at New Orleans. Dr. Miles Anderson of the University of California at Los Angeles prepared the 1956 tests. The examining staff included Dr. Robert Mazet, Jr., Dr. Rufus Alldredge, Mr. Howard R. Thranhardt, C.P., and the following Staff Examiners: Dr. Harry D.

Morris, Dr. Daniel C. Riordan, and Dr. Jack K. Wickstrom; and Prosthetists-Orthotists: Mr. Milburn J. Benjamin, Mr. Karl W. Buschenfeldt, Mr. Alfons Glaubitz, Mr. Erich Hanicke, Mr. W. Frank Harmon, Mr. Herbert J. Hart, Mr. Matthew G. Laurence, Mr. Paul E. Leimkuehler, Mr. Alvin L. Muilenburg, Mr. James D. Snell, Mr. David E. Stolpe, and Mr. Jack Vollmer.

REVISTA DE ORTOPEDIA Y TRAUMATOLOGIA LATINO-AMERICANA

With the publication of the first issue of Volume I of the *Revista de Ortopedia y Traumatologia Latino-Americana*, a long-cherished dream has been realized. Collaboration among the orthopaedic and traumatological surgeons of the Latin-American countries is an accomplished fact.

The first definite forward step was the founding, in 1948, of the Sociedad Latino-Americana de Ortopedia y Traumatologia. A group of orthopaedic surgeons from different Latin-American countries gathered together at Acapulco, Mexico, and organized the Society. Dr. Juan Farill became its first President.

In 1950 the First Congress of the Society took place with meetings at Montevideo, at Buenos Aires, and at nearby Mar de Plata under the Presidency of Dr. Alberto Inclán. Over 300 orthopaedists and traumatologists attended. The Second Congress was even better attended. It was held at Rio de Janeiro under the Presidency of Dr. Oswaldo P. Campos; over 600 orthopaedists and traumatological surgeons were present. In spite of distance and difficulties of monetary exchange the Third Congress of the Society was held in Mexico City, January 16 to 21, 1956, under the Presidency of Dr. Alejandro Velasco Zimbrón. Again attendance exceeded 600.

The Society is represented in every Latin-American country; each national Society assumes the functions of a chapter of the larger organization; each appoints a member of the Executive Committee of the Society.

Confederation of the national societies in one great representative organization was inevitable; it was destined to flourish from the beginning. The free interchange of ideas, the stimulus of organized concerted effort beyond national boundaries and routine habits of thinking, accelerated research and development, the impetus to education—all these and other favoring influences have convincingly demonstrated the soundness and the enduring quality of the collaboration.

It is only natural that the cooperation would be extended, sooner or later, to include co-publication of an international Latin-American journal. It is this that has recently come to pass through the merger of four famous orthopaedic and traumatological publications—*Cirurgia Ortopédica y Traumatologia de la Habana*, edited by Dr. Alberto Inclán; *Anales de Ortopedia y Traumatología de México*, the official organ of the Sociedad Mexicana de Ortopedia; *Anales de Ortopedia y Traumatologia de Montevideo*, edited by Dr. José Luis Bado; and *Revista de Ortopedia y Traumatologia de Buenos Aires*, edited by Dr. José Valls.

The *Revista* is the official organ of publication of the Sociedad Latino-Americana. It will be published quarterly under the direction and editorship of Dr. José Valls of Buenos Aires.

Articles should be forwarded to the President of the author's national society who will refer them to the regional committee for approval or revision. Approved articles will then be submitted to the Editor of the *Revista* who in turn will submit them to the Editorial Committee for final approval.

Thus, in a single publication, there will be recorded the notable achievements of Latin-American orthopaedists and traumatologists. Here will be set down, readily accessible, the record of the developments in the specialty in those great countries. No surgeon can afford not to keep abreast of these advances.

The Journal applauds this momentous achievement and extends to the *Revista* congratulations and best wishes.

The Editor

Book Reviews

Die cervikalen Vertebral-Syndrome. Eine vorläufige Bilanz der Kliniker. R. Janzen, W. Tonnis, F. Reischauer, and others. Stuttgart, Georg Thieme Verlag, 1955. DM 7.80.

This seventy-page monograph consists of eleven papers and a discussion which were presented at the 111th Convention of the Association of Lower Rhine Westfalian Surgeons at Essen on September 18, 1954. The following aspects of the cervical syndrome are considered: (1) the neurological aspects; (2) the surgical treatment; (3) the conservative treatment; (4) the cervical spine and the heart; (5) neurological symptoms resulting from cervical osteochondrosis; (6) the neuroclinical findings; (7) humeroscapular periarthritis as a neurological symptom; (8) the insurance and compensation aspects and expert opinions; (9) damage to the spinal cord as a result of changes in the cervical intervertebral discs; (10) the "mechanical" origin of neuralgias and radicular syndromes; and (11) chiropractic treatment.

In this, as in any symposium, one finds contradictory conceptions of the pathogenesis, diagnosis, clinical features, and treatment of the condition under discussion. However, there is for the most part a general agreement concerning the role of the intervertebral foramina in the picture of cervical nerve-root irritation and compression. Throughout the various papers there is recognition of the significance of the cervical sympathetic nervous system in the cervical syndrome. Conservative treatment is signally stressed. Procaine injections or blocks for the relief of symptoms are used as "sovereign and effective means" of neural desensitization and their use is considered to be a way to eliminate the necessity for more general or radical types of therapy.

The interpretation of clinical materials is somewhat colored by the fact of government-insured practice. The pitfalls of iatrogenic symptoms are stressed.

Much of the writing is so impregnated with verbose philosophisms and analogies that one must search laboriously for the basic scientific facts in order to make a fair analysis. For the most part the opinions expressed are fundamentally sound and indicate that the thinking of these writers on this subject is somewhat in advance of that of many of our American writers.

The illustration on the jacket of the book shows the point of a needle placed through a posterior joint space. A needle placed in this way will not hit a nerve root, but will come in contact with the postero-inferior surface of the vertebral notch of the proximal portion of the vertebra, and novocaine injected through the needle will infiltrate the intervertebral foramen and the perineural structures instead of the nerve root itself. Figure 1, Page 11, is somewhat inaccurate also, inasmuch as it shows a lateral prolapse of an intervertebral disc, which does not occur in the cervical spine because of the lateral intervertebral joints.

This monograph should be of interest to the orthopaedist, the neurologist, the surgeon, and the internist, and it should be provocative of further research on the cervical spine.

Ruth Jackson, M.D.

Medical Research: A Midcentury Survey. Vol. 1. American Medical Research in Principle and Practice. Vol. 2. Unsolved Clinical Problems in Biological Perspective. Boston, Published for the American Foundation, Little Brown and Company, 1955. Two volumes, $15.00.

It is hard to deal with this work without superlatives. It is an encyclopedic synthesis of information gathered by many workers from many sources yet chapter follows chapter with as much smoothness and lucidity as if it had been written by one brilliant author. It is typically the sort of undertaking that takes so long that it is out-of-date before it leaves the press. This work is astonishing in that so many of its references are so recent; it is a report of work in progress as well as a survey of a half-century. Probably few people will settle down to read both volumes from cover to cover but it is hard to vizualize the medical man who will not find in them something of specific value or, for that matter, the literate layman who will not find something of interest.

The non-medical book reviews have already devoted an unusual amount of space to these volumes, centering their attention for the most part on the second volume which is devoted to surveys of research in cancer, infertility, arteriosclerosis, hypertension, the rheumatic syndromes, tuberculosis, the nature of viruses and of virus diseases, alcoholism, and the biology of schizophrenia. Interesting and important as these are, it is probable that it will be Volume 1 that will become the *vade mecum* of the researcher himself and especially of the young and the potential researcher.

This volume is devoted to research itself, to its philosophy, its approaches, its problems. The emphasis is on the expanding biological concepts in medical practice, the interrelation of the sciences in research, the contributions of chemistry, physics, and mathematics to biological and medical research. It discusses

clinical research, medical and surgical disciplines evolving in the perspective of biology, and basic science. It stresses the importance of all types of researchers, the pioneers, the investigators, the invaluable collectors of evidence.

Finally it gives an exhaustive report of where research is done, under what auspices, and how it is supported. This section, covering 450 pages, reviews university departments, medical schools, foundations, independently endowed research institutes, non-teaching hospitals and group clinics, industrial organizations, government agencies, scientific and professional societies, and national voluntary health associations. The information given here could save a would-be research worker reams of correspondence and miles of travel.

The work is completed by an extensive bibliography. The absence of a general index is to a great extent compensated for by detailed tables of contents preceding each chapter.

J. A. R.

Essentials of Biological and Medical Physics. Ralph W. Stacy, Ph.D., David T. Williams, Ph.D., Ralph E. Worden, M.D., and Rex O. McMorris, M.D., with an introduction by Otto Glasser, Ph.D., F.A.C.R. New York, McGraw-Hill Book Company, Inc., 1955. $8.50.

This is the first published textbook on biophysics. The authors have attempted to cover the many and varied facets of the subject including mechanics, thermodynamics, acoustics, light, gas, fluid flow, technical systems, and nuclear physics, all in 560 pages. As stated in the preface, "The principles set forth in this book had to be stated afresh; the information had to be gathered from myriads of monographs, research reports, and personal communications; and the text had to be geared to our own estimate of what the student needed and could absorb". Based on four years of teaching biophysics at the Ohio State University, it is designed to aid students of biology, physics, and medicine, not as an advanced reference but as a guide to enable readers of widely different backgrounds to approach this relatively new branch of science with more facility. At the end of each chapter are lists of references selected so as to provide more detail concerning the statements made in the text and more extensive bibliographies.

From the foregoing it will be evident that the goal set for this book is probably unattainable. The field is so vast that few readers will be equipped to comprehend all that is included. This is all the more true because in the interest of brevity only the minimum of explanation is offered concerning the derivation of many of the equations and the theoretical analyses. Certainly the average medical student and doctor with a background of college mathematics and physics will be quite incapable of following some of the discussions without extensive collateral reading. Most orthopaedic surgeons will gain little by attempting to read the book from cover to cover unless prepared to review thoroughly physiology and physics at the very outset.

However, this textbook will be found to be of great value as a source book for the study of some particular aspect of biophysics be it biomechanics, the biophysics of muscle, electrophysiology, or radioactivity.

The clinician reading the chapters on the medical aspects of musculoskeletal engineering, on the application of heat in therapy, and on light as a therapeutic tool will wonder if they belong in this book. They seem rather brief and superficial. For instance, the statement that diathermy and ultrasonics "are of particular benefit in skeletal conditions, in chronic inflammations of abdominal and pelvic organs, in congestion, congestive chest conditions and in neuritis and neuralgia" is somewhat reminiscent of an advertisement for a patent medicine. At least to this reviewer's mind these sections strike a rather discordant note in a scientific work such as this.

In spite of this criticism, the authors are to be congratulated for their courage in attempting to organize the vast amount of material which this book covers. It is a real contribution and will prove to be a valuable starting point from which the student can launch his studies in the realm of biophysics.

Thornton Brown, M.D.

Posture and Pain. Henry O. Kendall, Florence P. Kendall, and Dorothy A. Boynton. Baltimore, The Williams and Wilkins Co., 1952. $7.00.

In his foreword to this book, Dr. Robert W. Johnson makes the statement that the Kendalls have had to have perfect teamwork, rare technical skill, great tenacity of purpose, and tireless enthusiasm to accomplish this work. The authors' integrity was well established when they, almost alone, among the country's physical therapists, stood by their convictions and opposed Sister Kenny's questionable idea of the pathology and the therapeutics of poliomyelitis. They have again shown the courage of their convictions by publishing a book on posture and pain in these days of antibiotics and steroids, which seem to dominate our therapeutics.

Body mechanics as we know it today originated with Dr. Goldthwait of Boston fifty years ago. This book goes further and develops Goldthwait's principles along practical lines.

The text is divided into four parts. In Part 1, body alignment, including posture standards and postural faults, is discussed. Part 2 is devoted to mobility. It deals with joint analyses in relation to posture, contains chapters on tests for muscle length and strength, and gives the procedure for postural examination. In

Part 3, there is one chapter on painful conditions of the low-back, the leg, the knee, and the foot, as well as a chapter on the upper parts of the back, the neck, and the arms. Part 4 deals with the prevention of postural faults, developmental factors, and environmental influences affecting posture.

Of special interest is the discussion of posture in relation to the feet and shoes. The authors give us many practical hints which have been gained by keen observation over a period of years.

The subject of body mechanics in normal and abnormal posture is gaining in importance in medicine. A book such as this fills a definite need. It is well written, the printing and paper are good, the illustrations are numerous and helpful, and the index is adequate.

In criticism, it might be mentioned that there is doubt that idiopathic scoliosis is caused by the carrying of books in one hand and that it is cured by exercises. The book deals mainly with static posture, and dynamic posture, or posture in motion, is somewhat neglected.

This book is recommended for physicians, physical-education students and teachers, and physical therapists.

K. G. Hansson, M.D.

YEAR BOOK OF ORTHOPEDICS AND TRAUMATIC SURGERY (1954–1955 Year Book Series). Edited by Edward L. Compere, M.D., F.A.C.S., F.I.C.S. Chicago, The Year Book Publishers, 1955. $6.00.

It is too easy to take for granted a volume, however useful, that appears in the same format, as regularly as the Summer Solestice. Fellow-editors, however, will look with great respect upon the industry and ability that has compressed within these familiar black-and-red covers two hundred and forty-one articles by three hundred and seven authors.

J. A. R.

TRANSPLANTATION OF TISSUES. Vol. 1. Lyndon A. Peer, M.D. Baltimore, The Williams and Wilkins Co., 1955. $13.50.

Dr. Lyndon A. Peer is a plastic surgeon of wide experience and has long been known for his interest and investigations in tissue transplantation. In undertaking a survey of this subject he has accomplished a difficult task with succinctness and thoroughness.

The contents of the book are well organized. Part I discusses human tissue cells, their environments, and their special roles. The short chapters on the intercellular substances, a field of rapidly expanding knowledge, and on methods of study of tissues and grafts are especially valuable. This part ends with a general discussion of the problems of heterogenous, homogenous, and autogenous tissue grafting. Parts II, III, IV, and V discuss the grafting of special tissues, namely cartilage, bone, fascia and tendon, and muscle. Each part contains a discussion of the normal structure of the tissue, a survey of pertinent literature on animal and human experimentation, and a consideration of the clinical use of the tissue in grafting. A brief summary at the end of each of these chapters is given. A noteworthy feature is the separation of the animal experimental work from that done in human patients, sharply differentiating between the two, since what holds for one may be by no means true for the other. Part VI in conclusion discusses theories of cell regeneration, especially the host replacement as against the cell survival.

The bibliography, although making no claim to being exhaustive, is well selected and one of the most important assets of the book. The illustrations in black and white are good and the histological sections are well reproduced.

The impress of Dr. Peer's own extensive experience and strong personality is seen throughout the book. The very nature of the subject is controversial and complete agreement with all statements is not to be expected. The conciseness and clarity with which this book is written strongly recommends it to all orthopaedic surgeons, and particularly to those with a special interest in tissue transplantation. It is to be hoped that Vol. 2 will soon appear.

Charles H. Herndon, M.D.

PRINCIPLES OF OCCUPATIONAL THERAPY. Ed. 2. Helen S. Willard, B.A., O.T.R., and Claire S. Spackman, B.S., M.S. (Ed.), O.T.R. Philadelphia, J. B. Lippincott Co., 1954. $5.50.

This new edition has been thoroughly revised so as to serve as an up-to-date text for students of occupational therapy. It is much needed in view of the increasing demand for occupational therapy as one of the adjuncts of medical rehabilitation services. In addition to its usefulness as a text, it will serve as a necessary reference for physicians and administrators directing rehabilitation programs in general, mental, and tuberculosis hospitals and special clinics, centers, and workshops. It would be of more interest to the practising physician and surgeon if a chapter written by a doctor had been added in order to orient the medical profession as to the usefulness of occupational therapy for the patient and to give information as to adequate prescription and medical supervision.

Arthur L. Watkins, M.D.

INSTRUCTIONAL COURSE LECTURES, VOL. XII, The American Academy of Orthopaedic Surgeons. R. Beverley Raney, M.D., Editor. Ann Arbor, J. W. Edwards, 1955. $12.00.

This twelfth volume of The Instructional Course Lecture series of The American Academy of Orthopaedic Surgeons is made up of articles based on selected lectures from the Instructional Course Program of the 1955 meeting of The Academy and constitutes an extension of The Academy's postgraduate teaching program. The volume contains a lecture on medical writing, four lectures on traumatic lesions, three on congenital anomalies, two on plastic surgery, two on physiology and biochemistry, two on pathomechanics, two on amputations, and one lecture each on arthrodesis, cerebral palsy, tumors, myelography, scoliosis, cardiac arrest, medico-legal aspects, and disability evaluation.

J. A. R.

CLINICAL ROENTGENOLOGY. Vol. I. Developmental and Systemic Condition and Local Lesions in the Extremities. Alfred A. de Lorimier, M.D., Henry G. Moehring, M.D., and John R. Hannan, M.D. Springfield, Illinois, Charles C. Thomas, 1954. $18.50.

This is the first of four volumes in an attempt to cover the entire field of diagnostic roentgenology. The authors gathered the great bulk of their material while they were in military service and freely give credit to the many roentgenologists and other physicians who provided them with roentgenograms and pathological specimens of conditions which they personally had not encountered. This work is an outgrowth of lectures given by them at the Army School of Roentgenology. Faced with the necessity of imparting information in short, intensive courses, they adopted a system of presentation to cover the clinical, roentgenographic, laboratory, and gross and microscopic pathological findings. Particularly, they have sought to emphasize the importance of not being "picture doctors", but of giving due consideration to the roentgenographic and clinical evidence in differential diagnosis. They have succeeded in gathering together a large amount of material and in condensing it. Each subject is discussed under the following headings: General considerations, roentgenographic manifestations, clinical corroboration, laboratory corroboration (including histopathological appearance), and differential considerations. A comprehensive bibliography is appended to each chapter. The roentgenographic manifestations are generally listed in outline form; while this does not make for as palatable reading as lucid prose, it does possess the merit of spatial brevity. The individual entities are presented as separate chapters with chapter sequence determined by the major pathological groupings.

Beneath each chapter heading, there is a listing of minor variants and ambiguous terms. This unfortunately is often confusing and misleading to the reader and, in certain instances, was apparently confusing to the authors. In the attempt to include some mention of all subjects in limited space certain entities have been discussed as a group. Thus under calcifying hematoma, both this lesion and generalized progressive myositis ossificans are discussed without clear-cut differentiation of the latter and with the unfortunate omission of associated skeletal changes. Under hypoparathyroidism, pseudohypoparathyroidism is discussed without clearly indicating the congenital nature of this disease. The discussion of the xanthomatoses and osteochondritis is rather sketchy; it might have been desirable to have elaborated further upon these subjects. Other minor omissions include lack of description of the rather pathognomonic changes in the hand in hyperparathyroidism and the frequent occurrence of proliferative changes in the vertebrae with an eosinophilic pituitary adenoma. There is a rather confusing discussion of the etiology of basophilism and some outmoded ideas are presented. Under chronic toxic proliferative periostitis, due to an oversight, there is no mention of peripheral malignant lesions of the lung in the listing of etiologic factors. An illustration is used of tardive heredosyphilis which bears a striking resemblance to Engelmann's disease or progressive diaphyseal dysplasia, although there is certainly no reason why the syphilitic process could not result in the same bone changes.

The vast amount of information available in this volume and its systematic presentation far outweigh any of the small errors or omissions which inevitably creep into a first edition. Particularly commendable are the introductory chapters dealing with the method of approach to film interpretation, technical aspects, and developmental considerations, as well as the chapter on fractures of the extremities. The book is profusely illustrated with reproductions of roentgenograms of generally excellent quality with complete legends. Many photomicrographs are shown. The book should be of particular value and interest to roentgenologists and orthopaedic surgeons.

Joseph Hanelin, M.D.

FRACTURES IN CHILDREN. Walter P. Blount, M.D. Baltimore, The Williams and Wilkins Co., 1954. $9.50.

This excellent book emphasizes the need for special consideration in the treatment of fractures in children. The section dealing with the necessity to avoid open reduction of fractures in children would alone make this book a valuable contribution to the orthopaedic literature.

The particular problems of diagnosis and treatment of fractures in children, as they differ from diagnosis and treatment of adult fractures, are clearly presented. The complications of epiphyseal injuries are simply

defined and the suggestions made by the author regarding the management of such injuries are sound, practical guides.

The book is well illustrated with roentgenograms of typical fractures and diagrams illustrating methods of reduction and traction. The relative incidence of various fractures and the mechanism of fracture are discussed. The complications of fractures are presented and emphasis is placed upon the prevention of these.

David S. Grice, M.D.

SURGICAL FORUM: PROCEEDINGS OF THE FORUM SESSIONS. Fortieth Clinical Congress of The American College of Surgeons, Atlantic City, New Jersey, November 1954. Philadelphia, W. B. Saunders Co., 1955. $10.00.

This distinguished volume, the fifth in its series, contains the papers selected for presentation at the Forum Clinical Congress of the American College of Surgeons at Atlantic City in 1954. As a whole it is one more piece of evidence that the isolation of surgery from its sister sciences is disappearing and the horizon of the surgeon has extended to embrace biochemistry, physiology, and biophysics. The main divisions of this volume and the number of articles in each division give the best picture of the scope of the material: Heart and Great Vessels (25); Blood Vessels and Circulation (16); Vascular Grafts (8); Esophagus, Stomach and Intestine (13); Liver and Pancreas (15); Nutrition, Body Fluids and Metabolism (25); Steroids and Cancer (21); Anesthesiology (11); Burns (8); Shock and Wounds; Plastic Anatomic Cast (11).

J. A. R.

SURGERY OF THE ELBOW. Frederick M. Smith, M.D. Springfield, Illinois, Charles C. Thomas, 1954. $10.75.

Here is an excellent book on surgery of the elbow. It is well planned and is written in a clear, pleasing style that not only holds the interest of the reader but stimulates his thought. The author has treated a somewhat controversial subject in a broad way and has given due respect to ideas that might not coincide with his own. One gains the impression as he reads the book that the writer is speaking from a broad and sound experience and that the book is based on careful observation and a great deal of work in this special field of surgery. His great interest and enthusiasm for his subject is evident, yet he does not allow this to color the scientific truths that he wishes to present. Such consideration and treatment make this book a pleasure to read, as well as a source of important information.

Since the subject matter of such a book is frequently of a controversial nature, there are bound to be differences of opinion concerning the various topics that are discussed; yet, for the most part, it is hard to find fault with most of the author's conceptions of the principles of treatment in surgery of the elbow. What differences there may be are usually of minor importance; some, however, should be mentioned.

For instance, under the heading "Dislocations", on page 9, is written "Certain types of dislocation at the elbow *must* have an associated fracture in order to make possible the dislocation. The best example of this is the anterior dislocation of both forearm bones upon the lower articular surface of the humerus, which cannot possibly take place without a fracture of the olecranon process of the ulna." A similar statement is made on page 12—"Anterior dislocations of the elbow cannot take place without a fracture of the olecranon." Now it is only fair to say that both of these statements are erroneous because we know that anterior dislocations of the elbow *can* and *do* occur without any associated fracture. To be sure, this type of dislocation without fracture is extremely rare and most of the anterior dislocations of the elbow do have associated fractures of the olecranon. Nevertheless, it is misleading to make such unqualified statements and, if one did not read on through the book, a false conclusion certainly would be gained. The author apparently recognized this fact, because in later chapters he reverses his stand and admits that there are on record authenticated instances of anterior dislocations of the elbow without any associated fractures.

In the discussion of "T" and "Y" fractures of the lower end of the humerus, there will be many surgeons who will take issue with the author on a number of points. They will find it difficult, for instance, to share the author's enthusiasm for the use of low-intensity heat applied continuously and gentle message done twice daily in the fractures treated in traction or by means of open reduction and will question the advantage of low-intensity heat and light-sedative massage as a means of reducing swelling in the early treatment of fractures. The author feels differently about massage when applied to children's elbow fractures and strongly emphasizes that it should never be employed. Also, he states "In supracondylar fractures in children diathermy and massage are practically worthless and very frequently cause harm and delayed recovery." With these two statements concerning the use of heat and massage in elbow fractures in children most fracture surgeons will agree, but why not include fractures in adults as well? In other words, just how effective a part can low-intensity heat and massage play in the early treatment of fractures? Certainly, if there should be any serious question regarding circulatory disturbance in the fractured joint, the use of heat would be dangerous. Heat is capable of doing so much harm in the early treatment of fractures and, at best, can do so very little good that many of us who treat fractures find we can get along very well without it—at least, until the later stages of treatment are reached.

The author's views on the optimum time for operating on paralyzed nerves associated with closed fractures is not too clear, since in one part of the book he states "These [injured nerves] should be treated conservatively at first and only operated upon later, if no improvement is noted in their function after four to six months". Later, speaking of nerve lesions at the elbow, the following statement is made: "The progress of recovery of the nerve should be frequently checked. If no evidence of recovery has appeared in three to four months, the nerve should be explored." Whether he considers four to six months or three to four months the optimum time for operation is probably of no great importance, but the question might well be raised if this period of waiting is not too long—particularly if the nerve is completely paralyzed. Would not a majority opinion deem it wiser and as saving a lot of time to explore the nerve earlier if the palsy is still present after three or four weeks with no apparent improvement?

Certain other ideas in this book will probably not pass unquestioned or be approved by most surgeons, such as (1) the advisability of using a transfixion screw across the line of fracture when plates are employed for internal fixation; (2) an anterolateral incision being the only correct one for excision of the radial head when the latter has been fractured at the time of a posterior dislocation of the elbow; (3) that separation of the epiphysis of the medial epicondyle of the humerus in children (often with the avulsed fragment displaced into the joint cavity) is frequently associated with posterior dislocation of the elbow (in our experience, the dislocation that produces this condition is lateral, not posterior); (4) the necessity or even advisability of hyperextending the forearm in the reduction of posterior dislocation of the elbow (is it not unnecessary and may it not do harm?); (5) that "rheumatoid arthritis affecting one or both elbows or other joints is due to infection, usually from the haemolytic streptococcus"; (6) that the best treatment for fractures of the capitellum in adults is to remove the fractured loose fragment rather than to replace it; (7) that the mechanism of Monteggia fractures is due almost always to direct force upon the posterior aspect of the ulna (this is the old conception, but seems to have been refuted successfully by Evans who showed that these fractures are the result of severe pronation injuries, not direct trauma).

The author's outline for "after-treatment" of posterior dislocations of the elbow is somewhat unorthodox and will probably be objected to by many fracture authorities. Certain questions will naturally arise concerning this regimen of treatment. For instance, is the immobilization period sufficiently long to allow good healing? Is not frequent, daily removal of the splint after two to three days following injury unnecessary and possibly asking for trouble when the patient at these times of exercising is permitted to extend the elbow to 130 degrees? Would not removal of the splint after one week, and of the entire protective apparatus after seventeen days, expose the joint to the danger of redislocation, especially since posterior dislocations of the elbow are very prone to recur if extension of the forearm bones inadvertently takes place?

In spite of controversial points, this book covers the subject of surgery of the elbow in a concise, well-organized manner and contains a great deal of good, common sense and sound judgment. The chapters on "The Pathology of Fracture", "Anatomy of the Elbow Region," and "General Considerations of the Patient" are very good. Also, the chapter on "Anaesthesia" is sensible, logical and well-presented. The section on "Volkmann's Ischaemic Contracture" is excellent.

The last two chapters on "Non-Traumatic Conditions of the Elbow" and "Special Operations upon the Elbow" are much too brief to cover their subjects adequately, but this may be necessary in a book of this size; the reader will, therefore, be obliged to consult separate authoritative sources if he is deeply interested in such conditions or types of surgery.

In a book of this character, it would be impossible, of course, to please and satisfy everybody, yet it comes very close to presenting the best current ideas on surgery of the elbow, and could well serve as a safe guide to younger surgeons who are interested in this field of work. The author is to be congratulated for a difficult accomplishment well done.

George W. Van Gorder, M.D.

PHYSIOLOGY AND ANATOMY, WITH PRACTICAL CONSIDERATIONS. Ed. 5. By Esther S. Greisheimer, B.S. (Ed.), M.A., Ph.D., M.D. Philadelphia, J. B. Lippincott Co., 1955. $5.00.

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The clear style of presentation and accuracy are to be commended. The introduction of new terminology for the student is managed well. There are definitions in parentheses, following the new words, as well as frequent cross references in the text.

The many schematic diagrams and charts are excellent teaching aids. Such a subject as the chloride shift is clearly and simply described by text and illustration.

The index, cross references, and glossary make this a workable text. Bold face type headings divide the page subject matter well.

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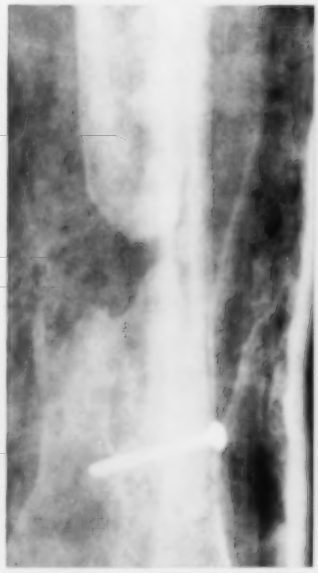

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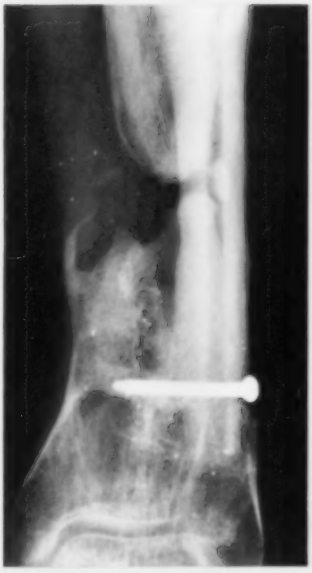

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RADIOGRAPHS: A-P preoperative and postoperative.

COLOR PHOTOGRAPHS: Surgical repair—6 views; this page and page following.

1. Left leg showing adherent scar over tibia. Large pedicle flap graft from opposite leg extends over to fibula.

2. Exposed *peroneus longus* muscle and fibula. Scarred extensor muscles being retracted from tibia and fibula.

3. Fibula sectioned about 4 centimeters above *malleolus*, and is being mobilized for insertion into tibia.

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RADIOGRAPHS: Lateral preoperative and postoperative.

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4. Foot displaced laterally correcting varus. Fibula being fastened into lateral side of tibia.

5. Stainless steel screw holds fibula firmly in cavity. Bone fragments packed in to insure solid healing.

6. Space between fibula and tibia above nonunion packed with autogenous cancellus bone and cortical bank bone.

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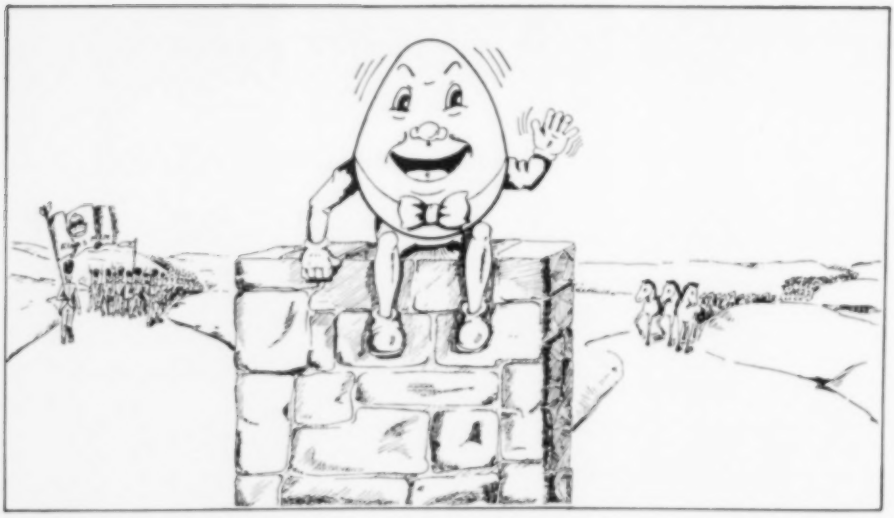

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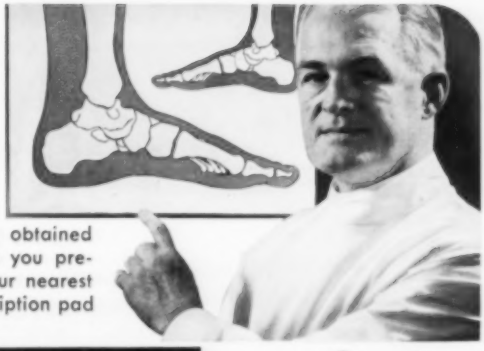

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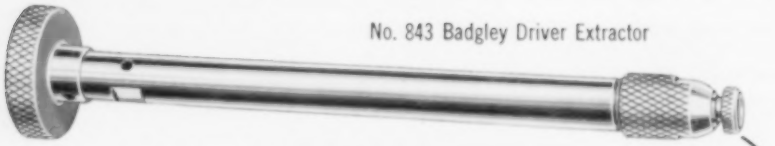

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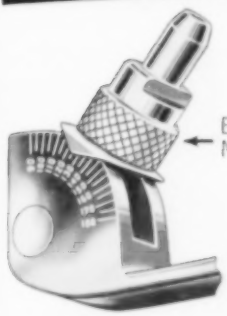

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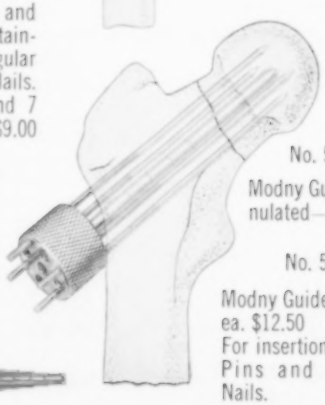

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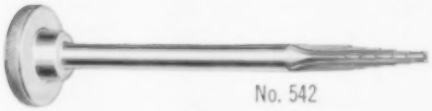

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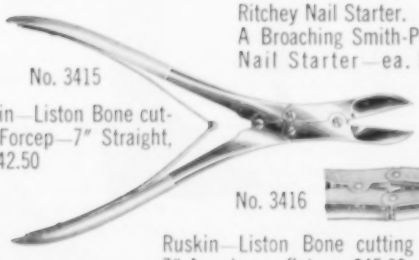

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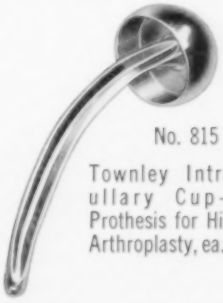

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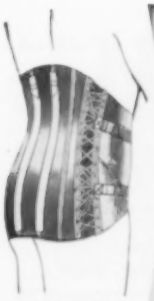

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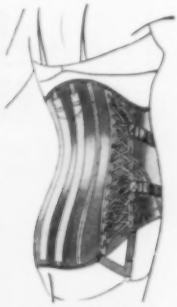

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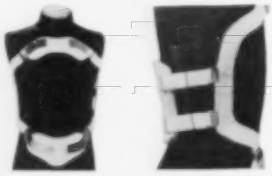

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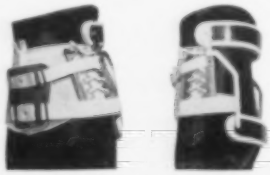

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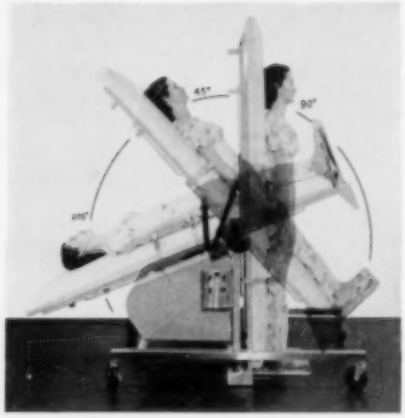

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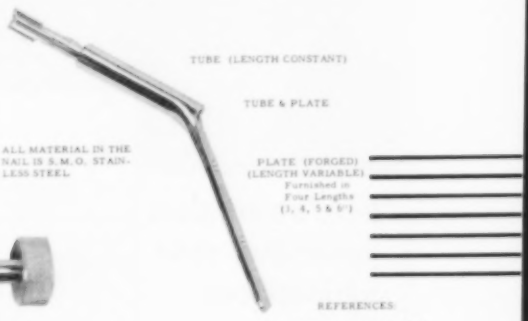
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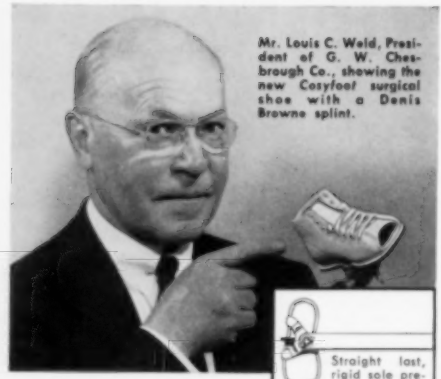

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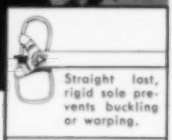

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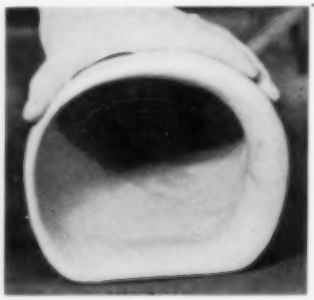

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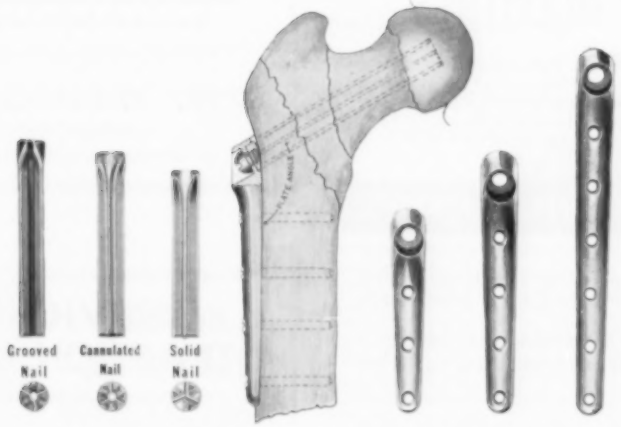

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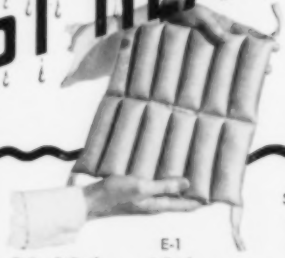

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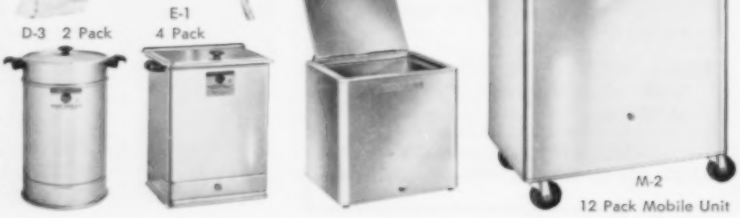

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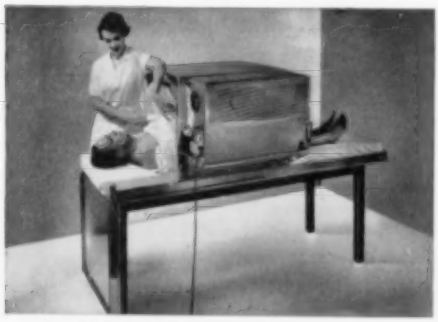

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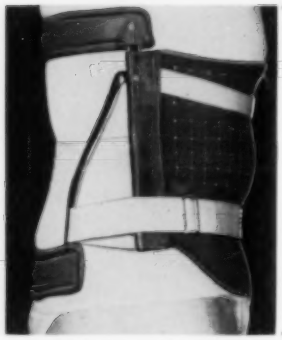

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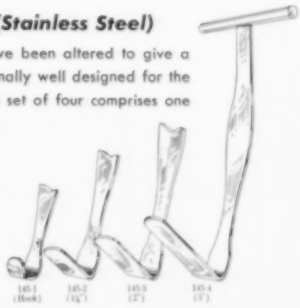

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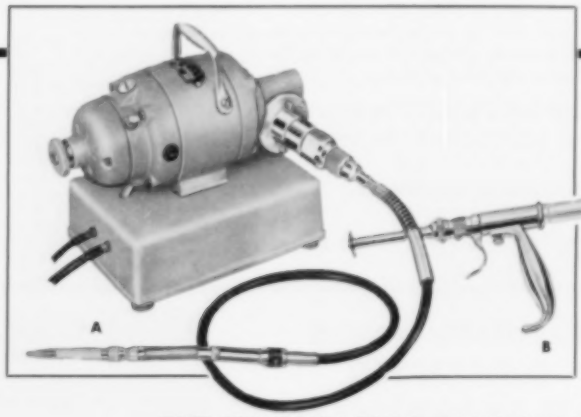

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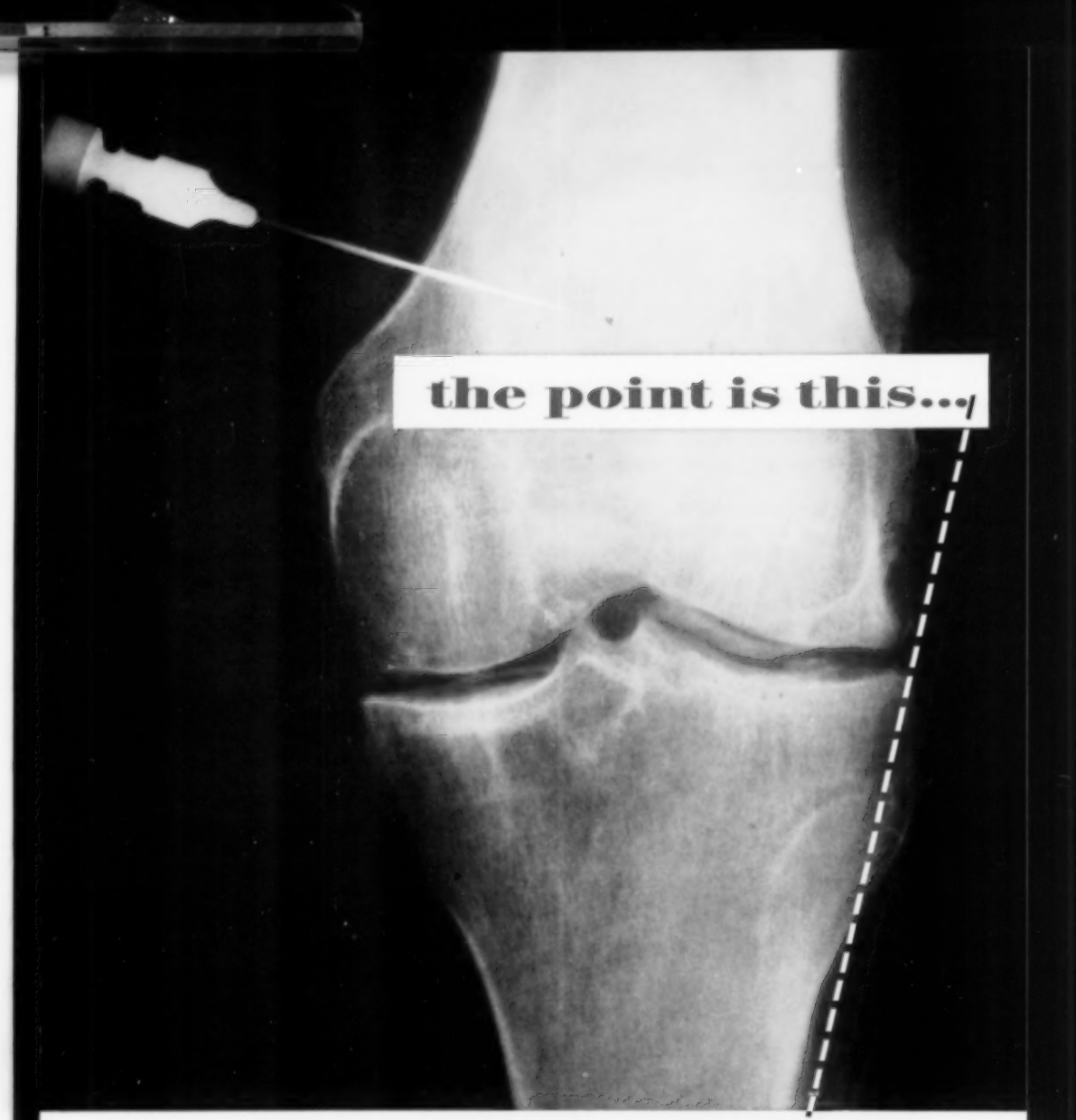

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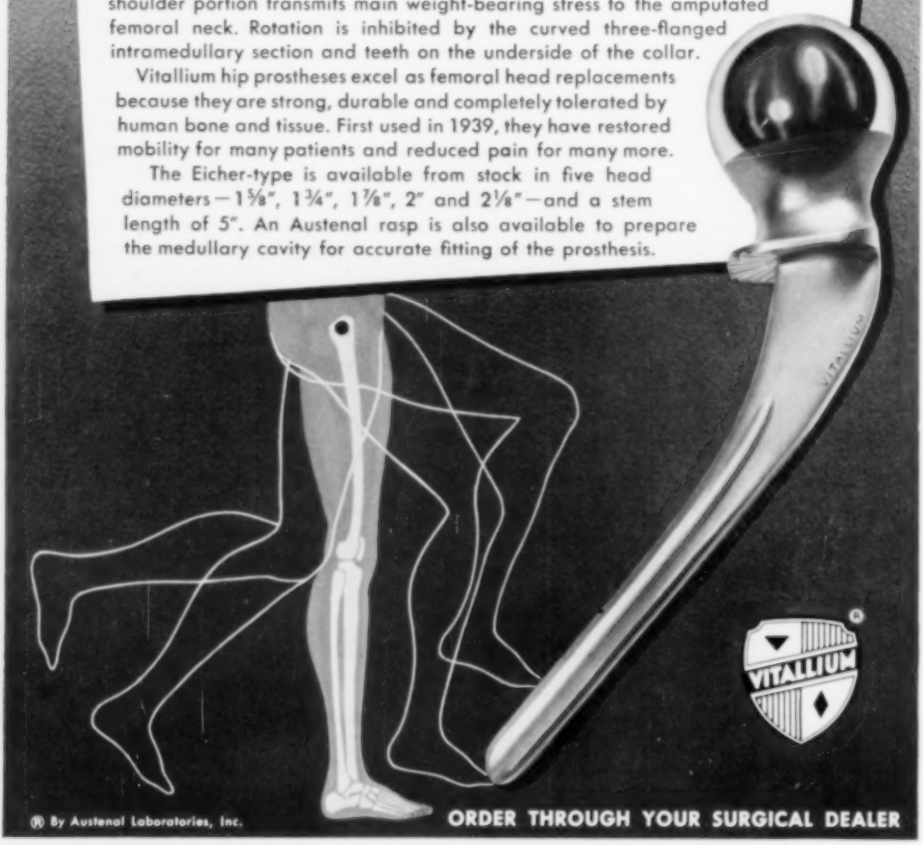

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